Understanding flash reconstruction

Bruce Howard and Denver Whittington
protoDUNE Measurements Meeting
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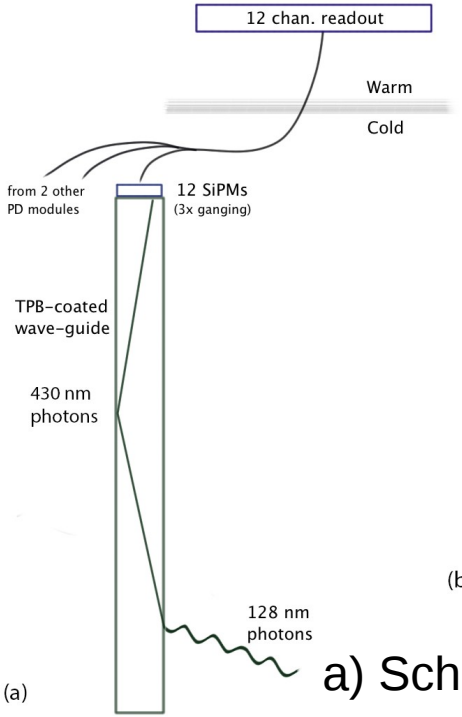
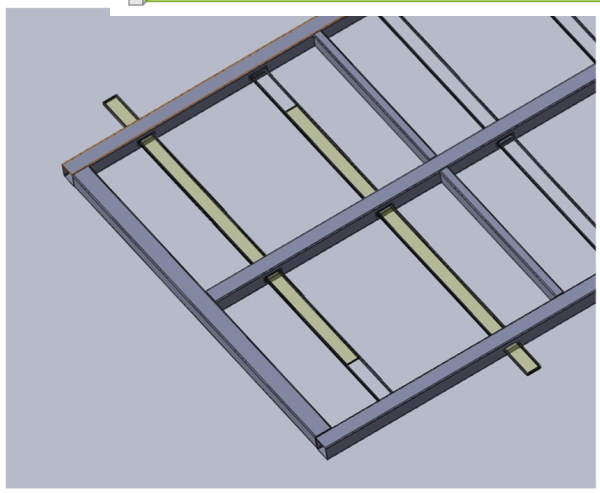
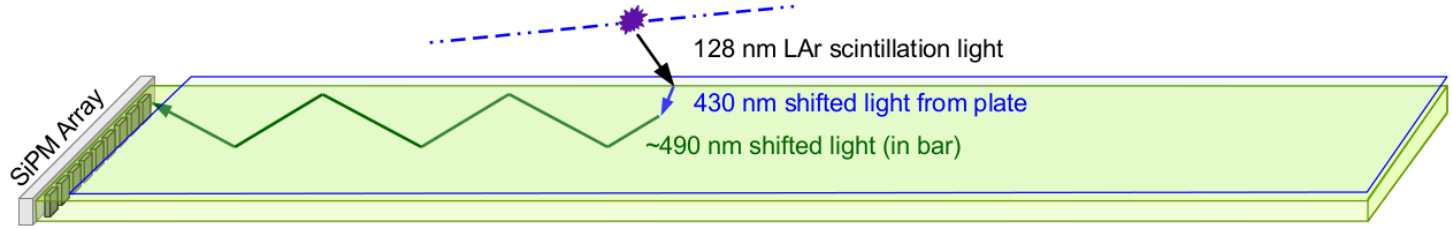
Photon Detection System

- The protoDUNE photon detection system uses wavelength shifters to convert the VUV scintillation from LAr to the visible spectrum and light-guides to transport the converted photons to an SiPM-based readout.
- 2 ~2m-long light-guides per APA → 10 light-guides per anode







Cartoon of another PD system design which utilizes a radiating plate along with a light-guide

a) Schematic of dipped light-guide PD system, b) PD system in APAs (from CDR)

Reconstruction Process

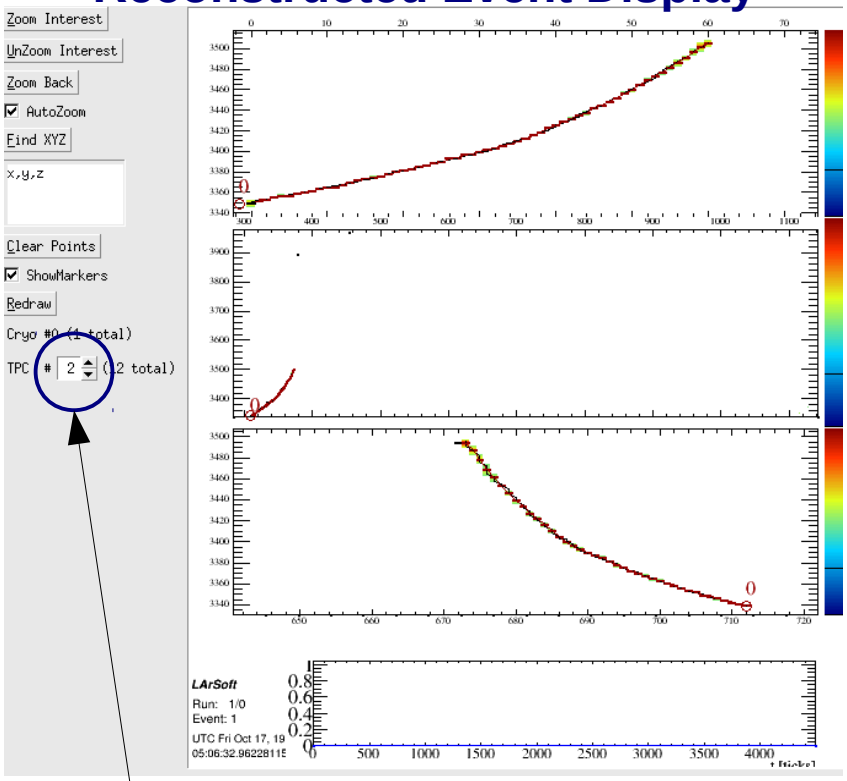
- Photon detector reconstruction has two main pieces, hits and flashes.
- “Hits” are basically what's recorded when a light-guide sees signal, e.g. peak time and number of photoelectrons (PE)
- Look for coincident hits, in other words the signals from light-guides which receive light from the same event
  - A “flash” is reconstructed in space by looking at the locations of the hits
    - Y and Z positions are the mean central positions of light-guides receiving signal (weighted by PE)
    - Width in i-direction calculated as (i = Y or Z):

$$\frac{\sqrt{PE_{\mathrm{tot}}(\Sigma_{\mathrm{hit}} PE_{\mathrm{hit}} i_{\mathrm{hit}}^2) - (\Sigma_{\mathrm{hit}} PE_{\mathrm{hit}} i_{\mathrm{hit}})^2}}{PE_{\mathrm{tot}}}$$

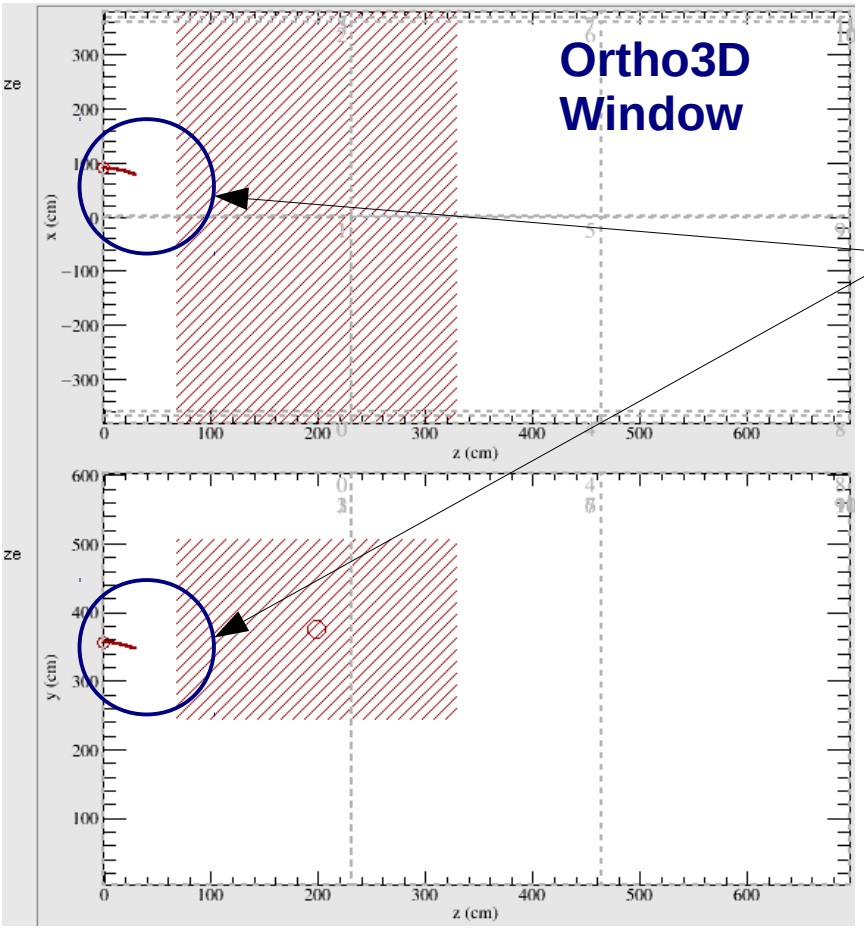
Motivation of this study

- Tingjun noted odd flash position in protoDUNE geometry.
  - Followed same simulation steps to reproduce problem
  - μ- with p0~200 MeV; x0=118.106 cm, y0=395.649 cm, z0=-196.113 cm

Reconstructed Event Display



Note: You must go to TPC 2!!



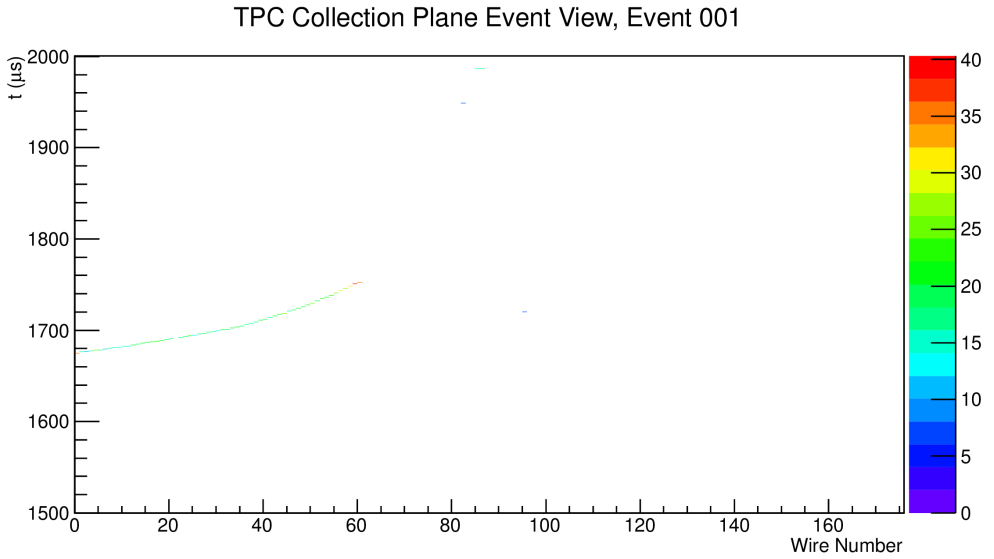
Reconstructed flash position is away from the reconstructed track for events entering from side of TPC

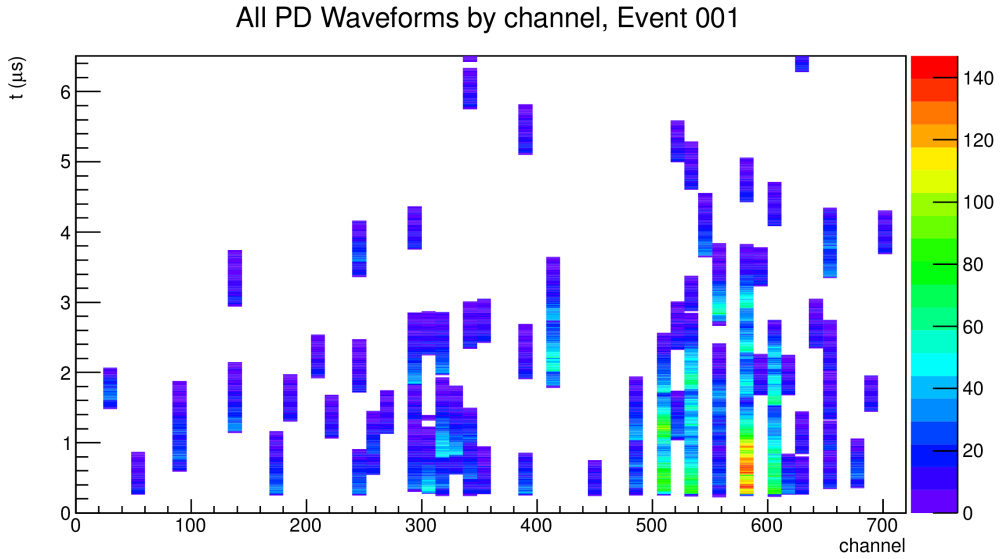
Motivation

- We want to understand what is being done in the flash reconstruction in Larsoft
  - Is something actually wrong? Do we see light where we should see light?
  - Why is the flash reco box so far from the actual track?
  - What can be done about this?
- DW wrote a module that takes generated simulation and produces digitized waveforms and TPC signals
  - Updated module to work in newer versions of Larsoft
  - Included a “channel map” which tells the x,y,z locations of the center of PD number
  - Ran output of detsim step (right before reconstruction) through this module – compare this to the sim chain described before

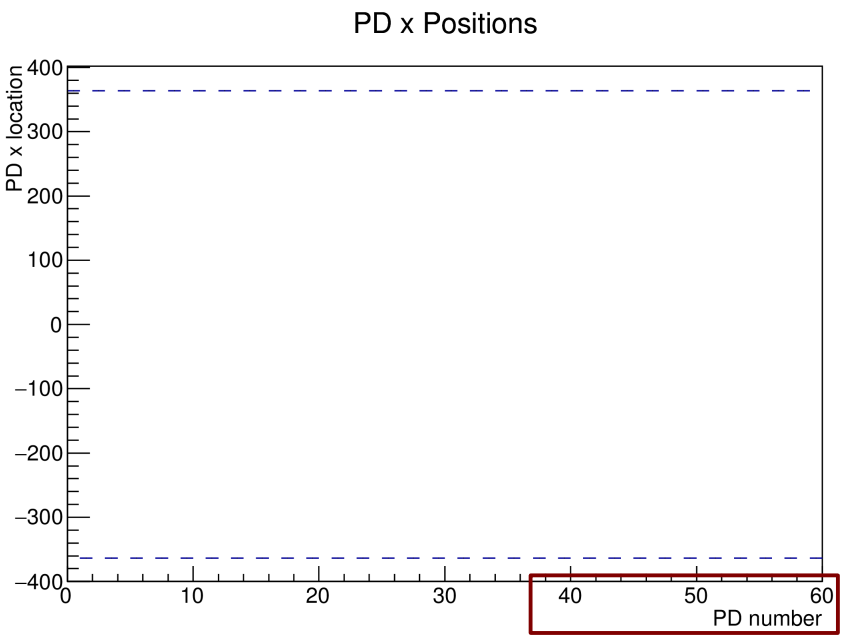
What do we see?

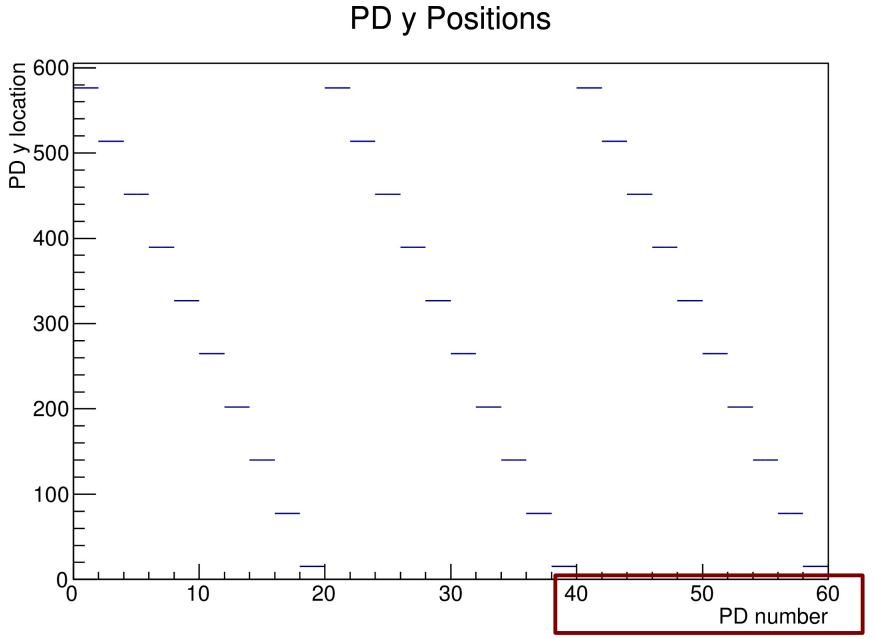
- Individual SiPM response show that PD module 576/12=48 sees brightest signals in this event.
- Look at region of interest in next slides
- Region of interest explored for other events in backup

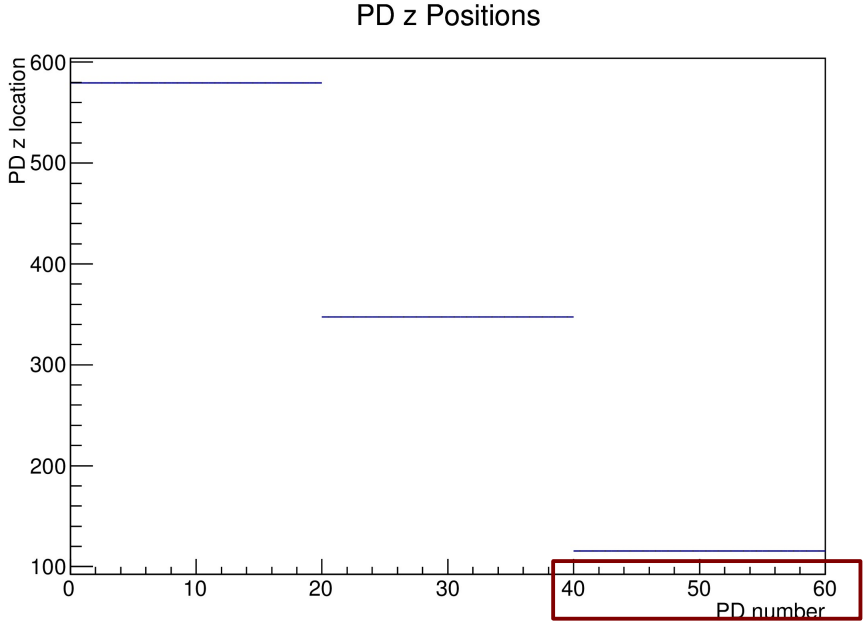




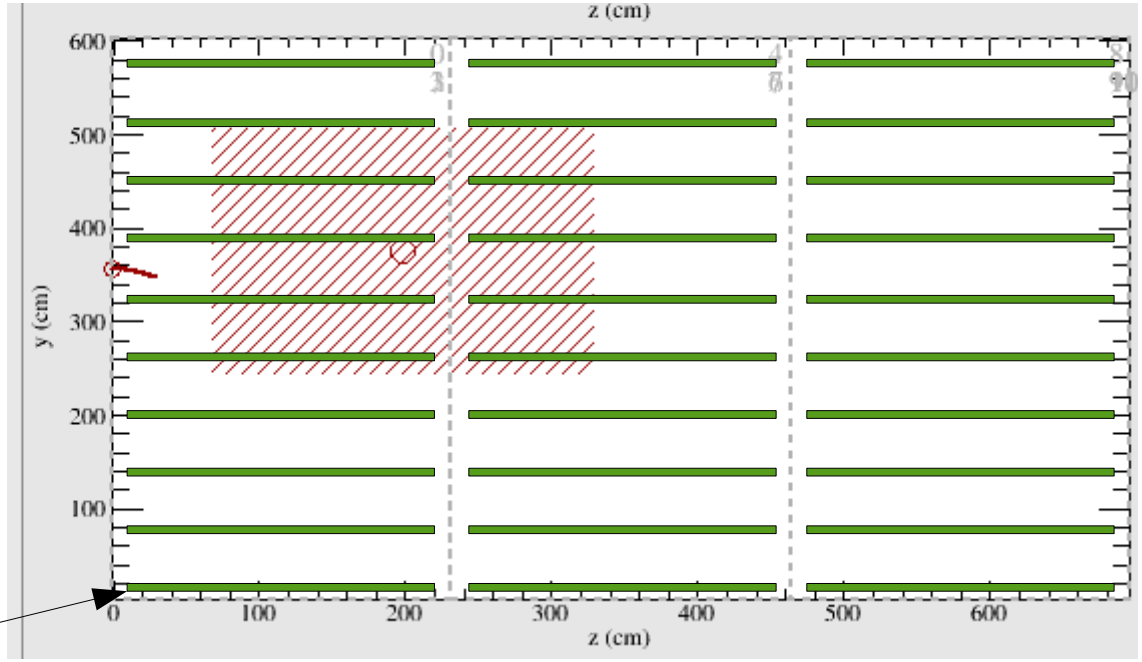
Channel Map


PD x Positions
PD x location
PD number


PD y Positions
PD y location
PD number


PD z Positions
PD z location
PD number

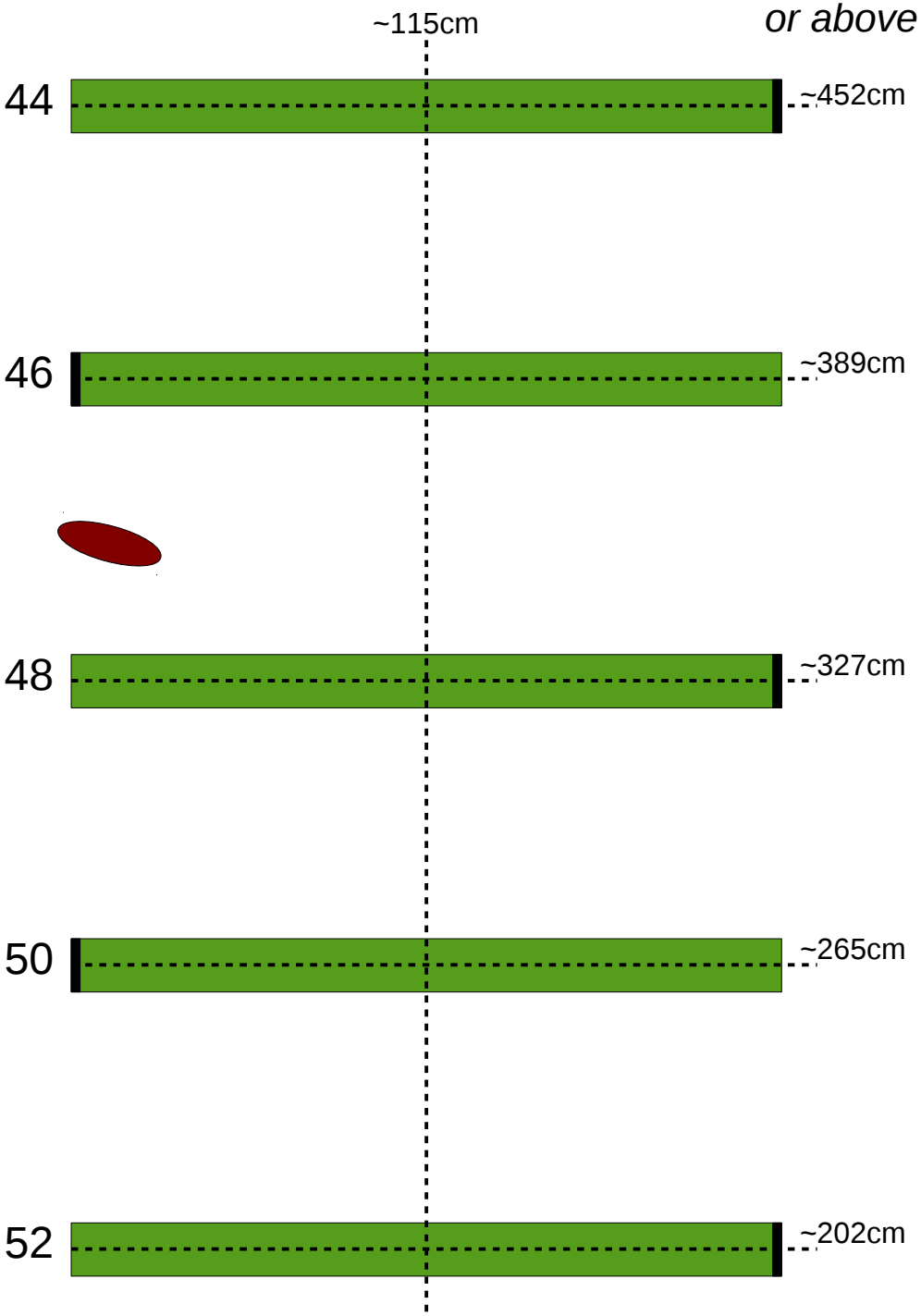
EVENT 1

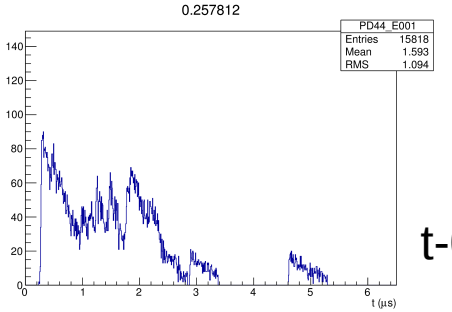


Readout end

EVENT 1

Approximate t-0 as low edge of first sample at or above 10ADC





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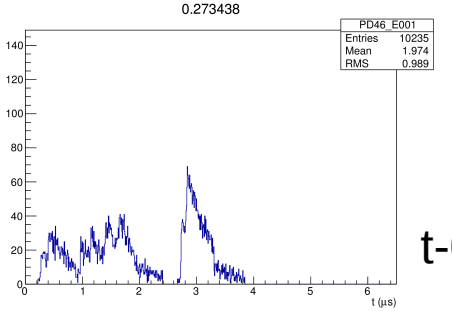

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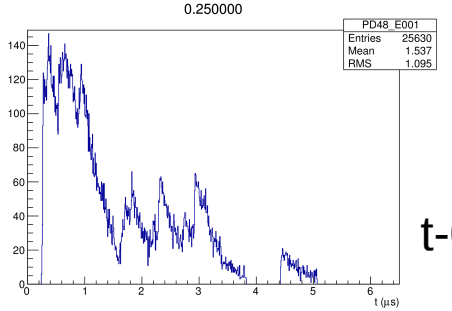

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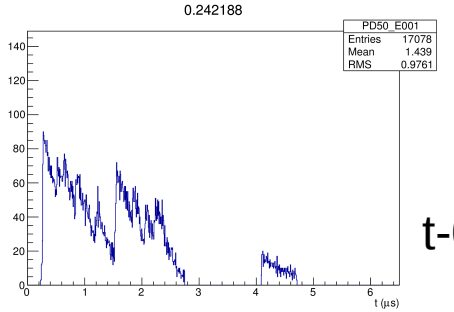

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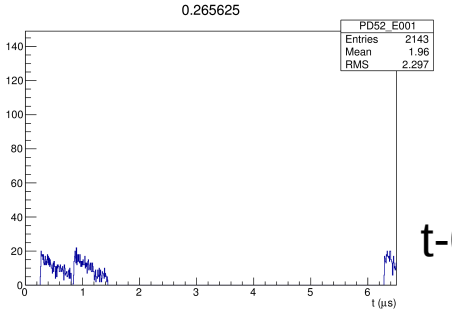


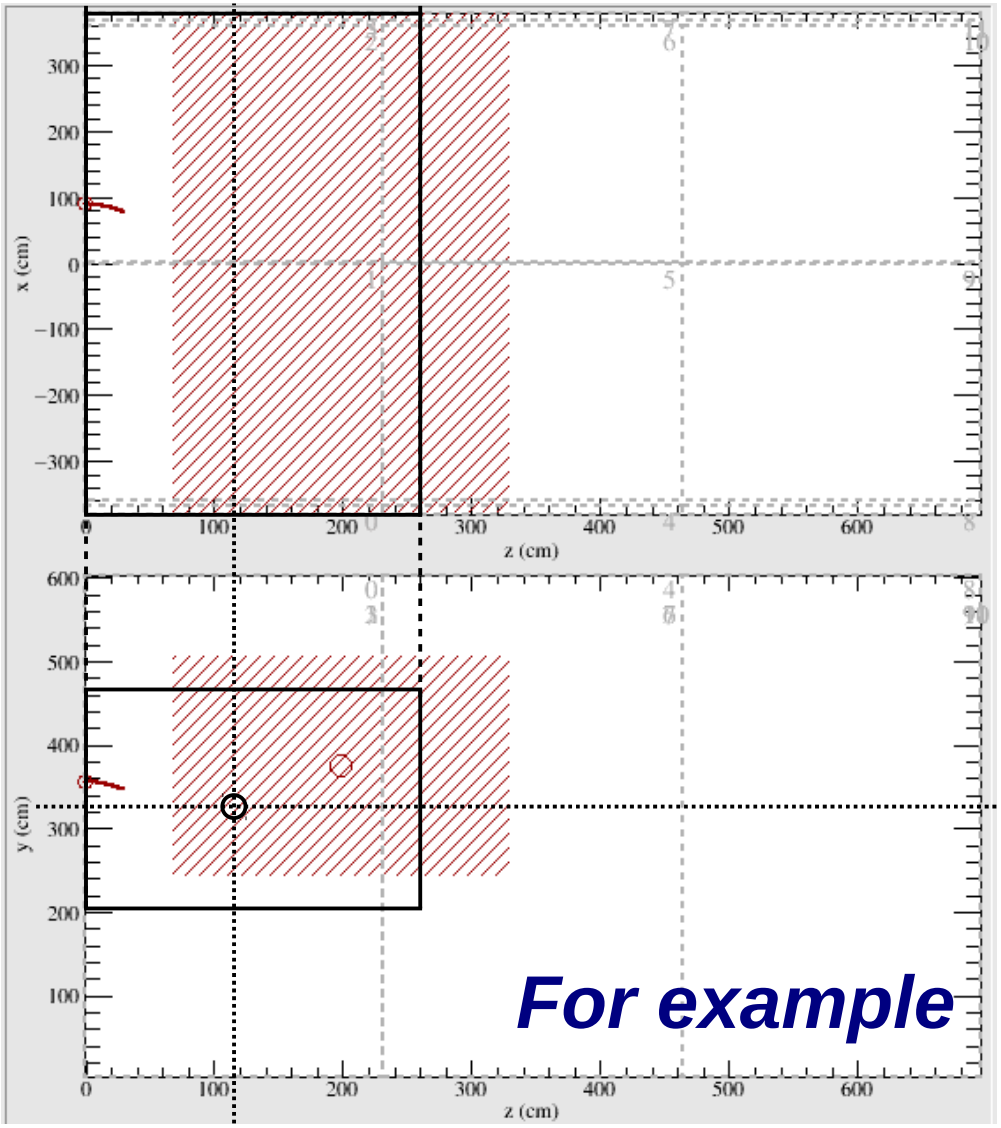
t-0 = .265625 μs

What's going on?

- So that all could make sense...but wait...then, why is the reconstructed flash position so far away from the track?
  - As Alex had originally thought, it's because of weighted means
- **Problem:** Using weighted mean of PD central positions from OpHits pulls the overall flash position away from true location, due to OpHits on neighboring APA(s)
  - Not finely-grained, especially if just use central positions
  - For events in edge APA, no OpHits on one side, so flashes get pulled further inside volume

Solution

- Define asymmetric box to compensate for lack of OpHits on other side of brightest PD module
  - Center = center of light-guide with brightest signal in event (instead of weighted mean)
  - Width = Asymmetrically defined by the distribution of other signals (instead of weighted deviation)
    - Size at least 1 light-guide by definition
  - Added benefit: large hit-box for tracks which span multiple APAs



Issues in implementing solution

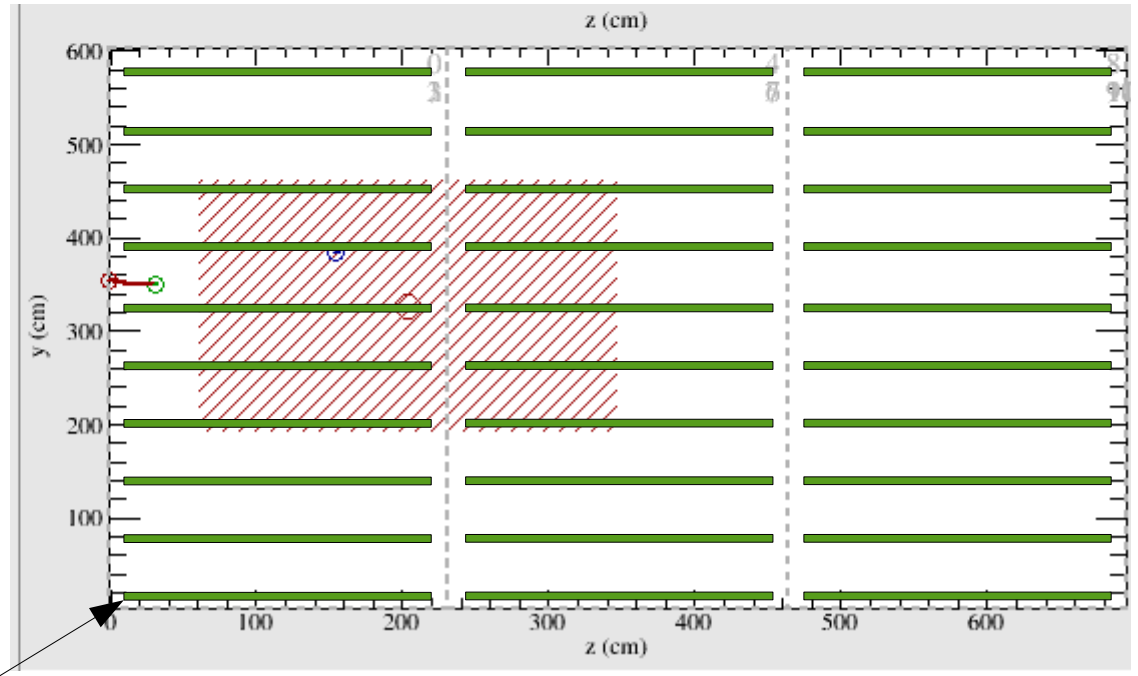
- The reconstruction code base is in general Larsoft code base, is in pieces of code also used by other experiments
  - **`lardata/RecoBase/OpHit`** & **`OpFlash`**
  - **`larana/OpticalDetector/OpFlashFinder_module`** & **`OpFlashAlg`**
- OpFlashFinder uses OpFlashAlg to produce OpFlashes using OpHits
  - OpFlashAlg uses weighted means of PD centers to determine a flash position and width
  - Using PD centers is fine for 8” PMTs but we have 2m long light-guides.
  - The assumption of symmetric width of flashes is too hard-coded in larana

Possible implementations

- Special case in larana: treat light-guides separately
  - **`geo::GeometryCore::OpDetGeoName(cryostatID) == “LightPaddle”`**
  - Then special calculations for these objects
  - Perhaps use readout ends (not just centers)
  - GDML has this in place
    - **`rotationref ref = “rIdentity”`** & **`“rPlus180AboutY”`**
  - Hope that this is enough to overcome the pull of weighted mean
- Reimplement a customized OpFlash and OpFlashFinder for DUNE, in dunetpc (Yikes!)
  - New code can use asymmetric box width/height
  - Use staggered readout ends to help localize flashes
  - Would allow customization of flash finding algorithm to deal with SiPM waveforms

BACKUP

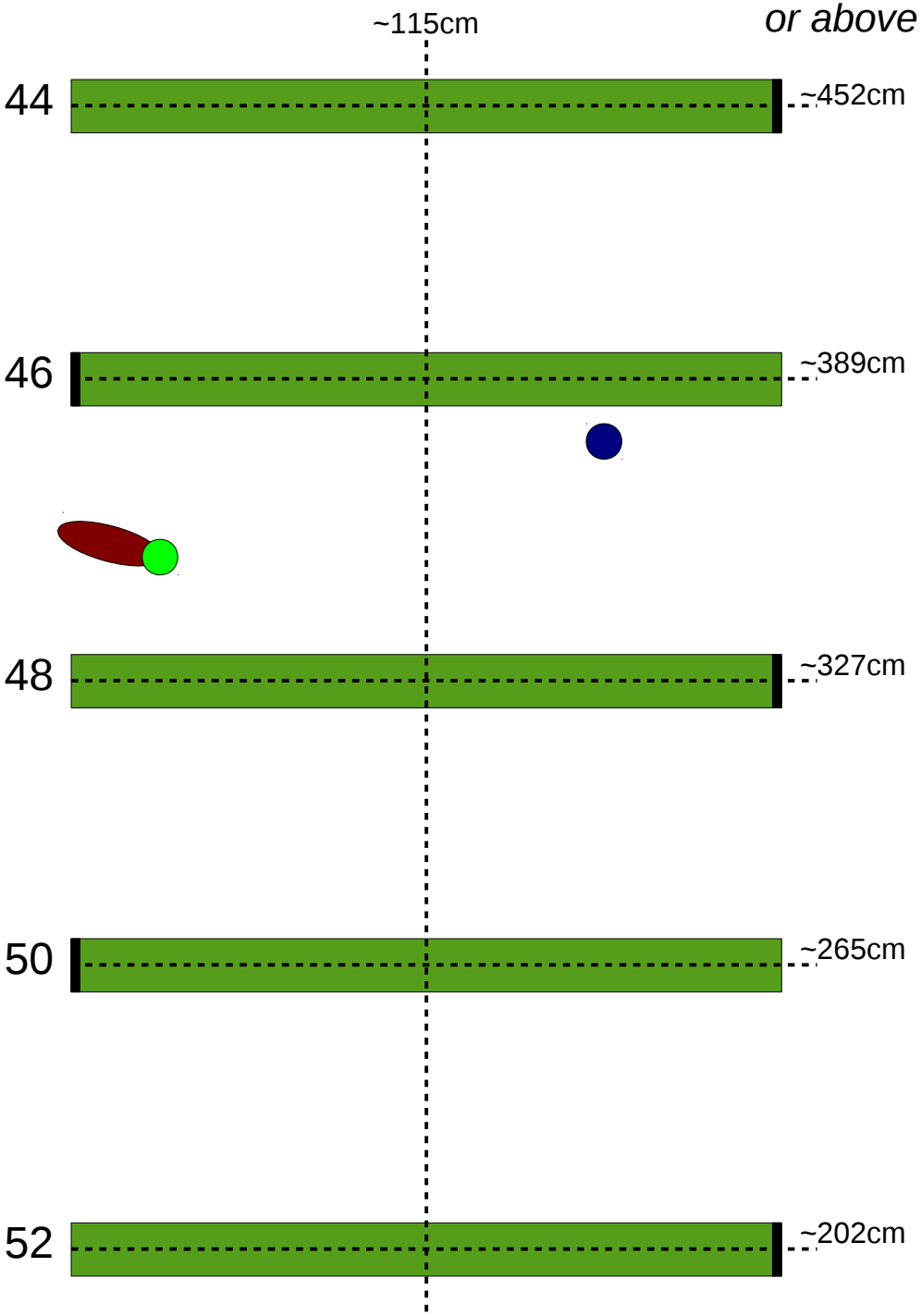
EVENT 2

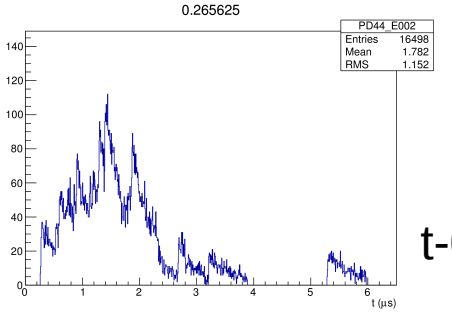


Readout end

EVENT 2

Approximate t-0 as low edge of first sample at or above 10ADC





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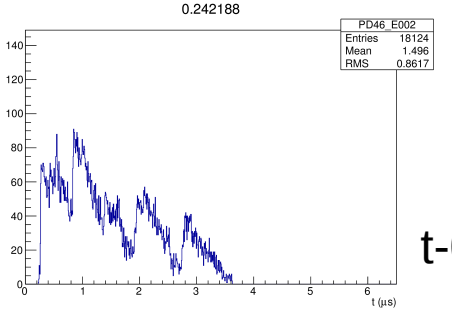

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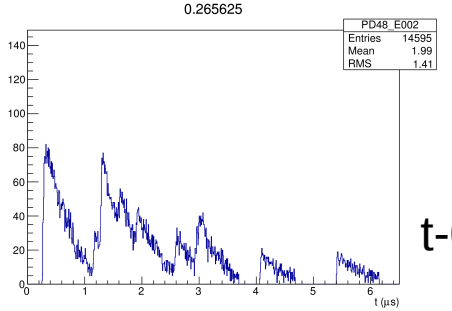

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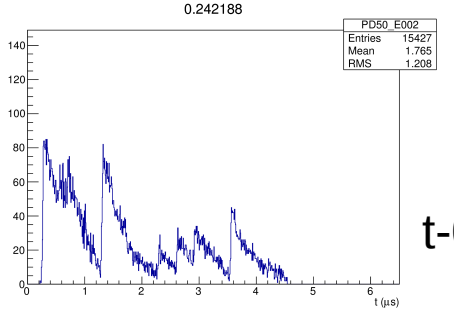

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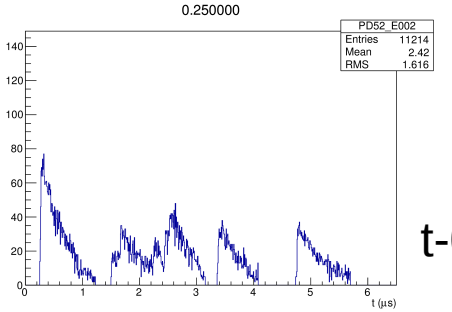

t-0 = .25 μs

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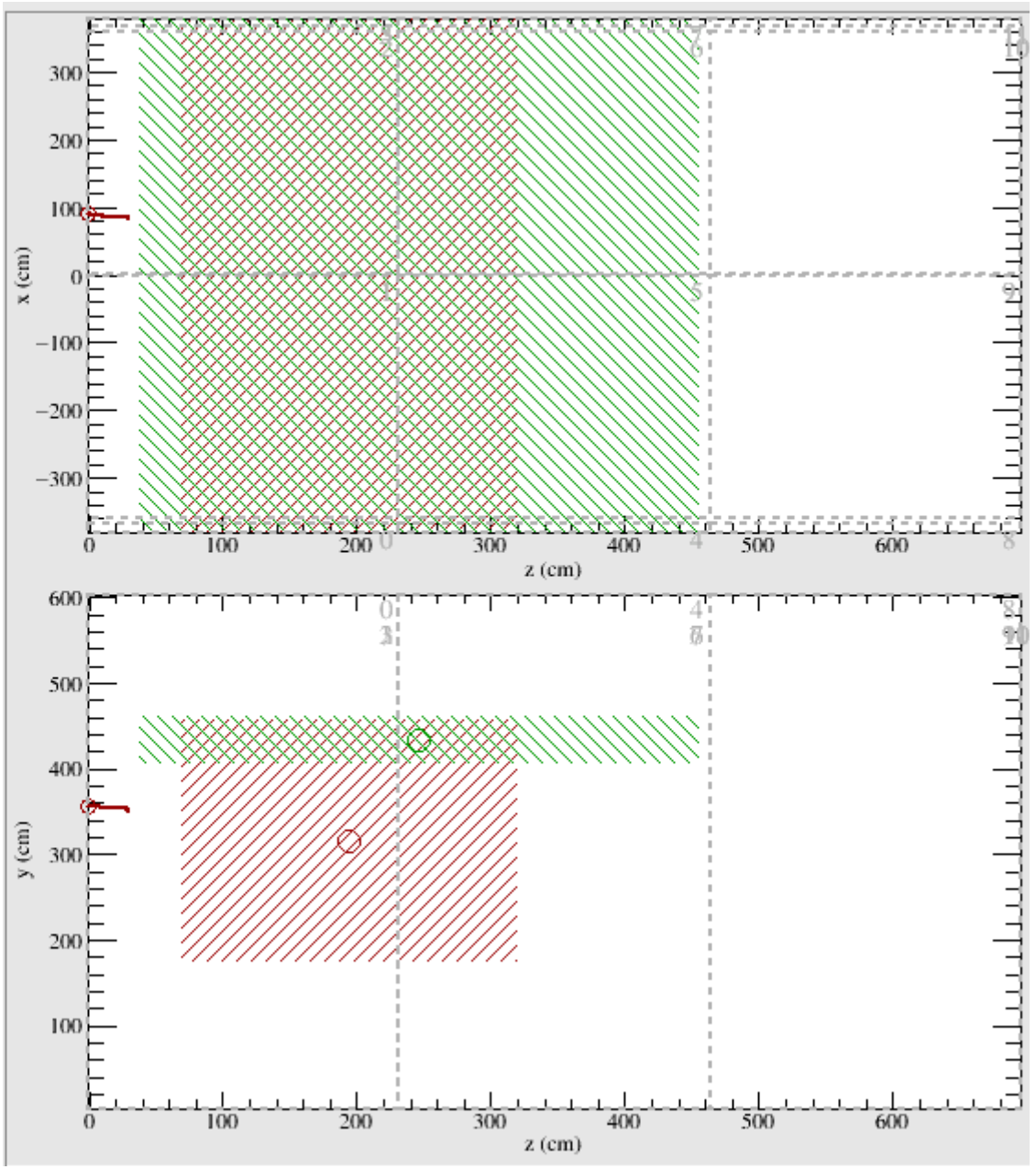
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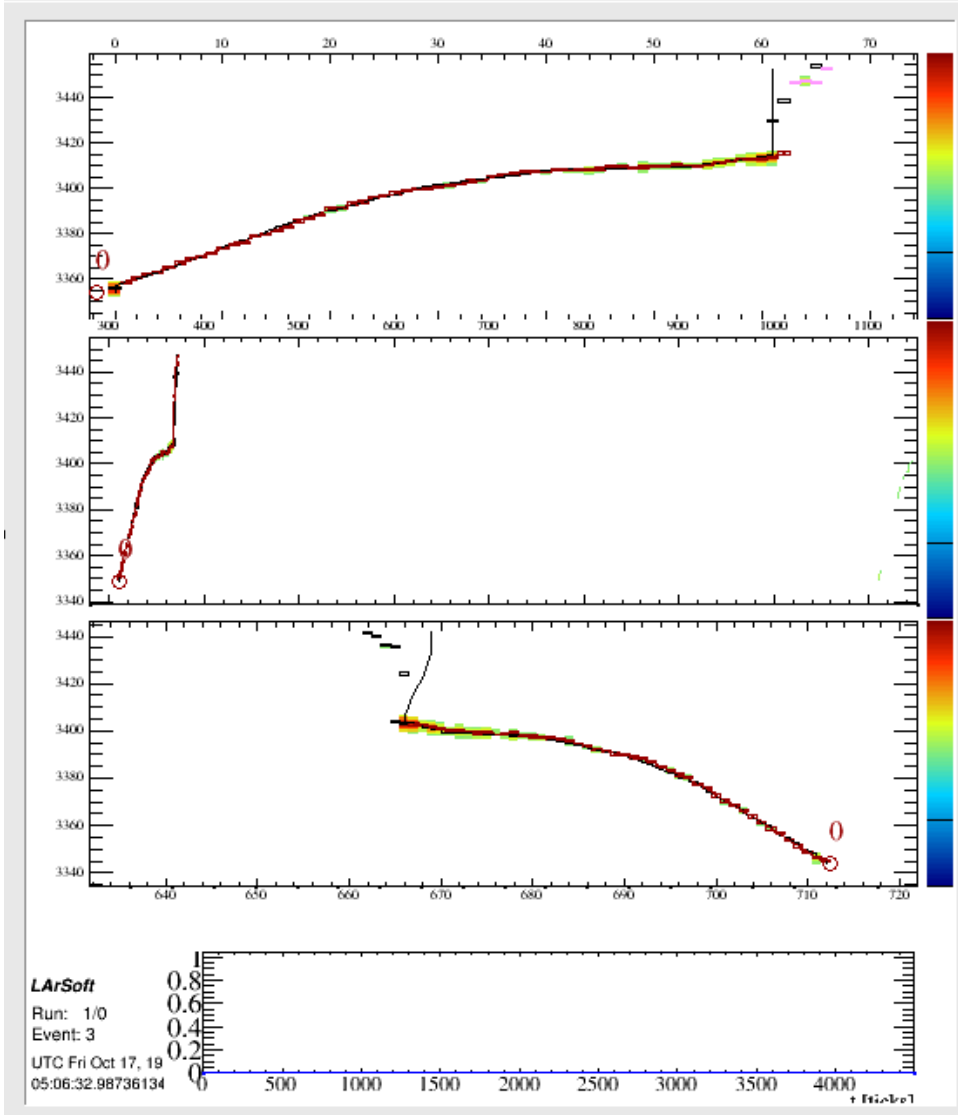
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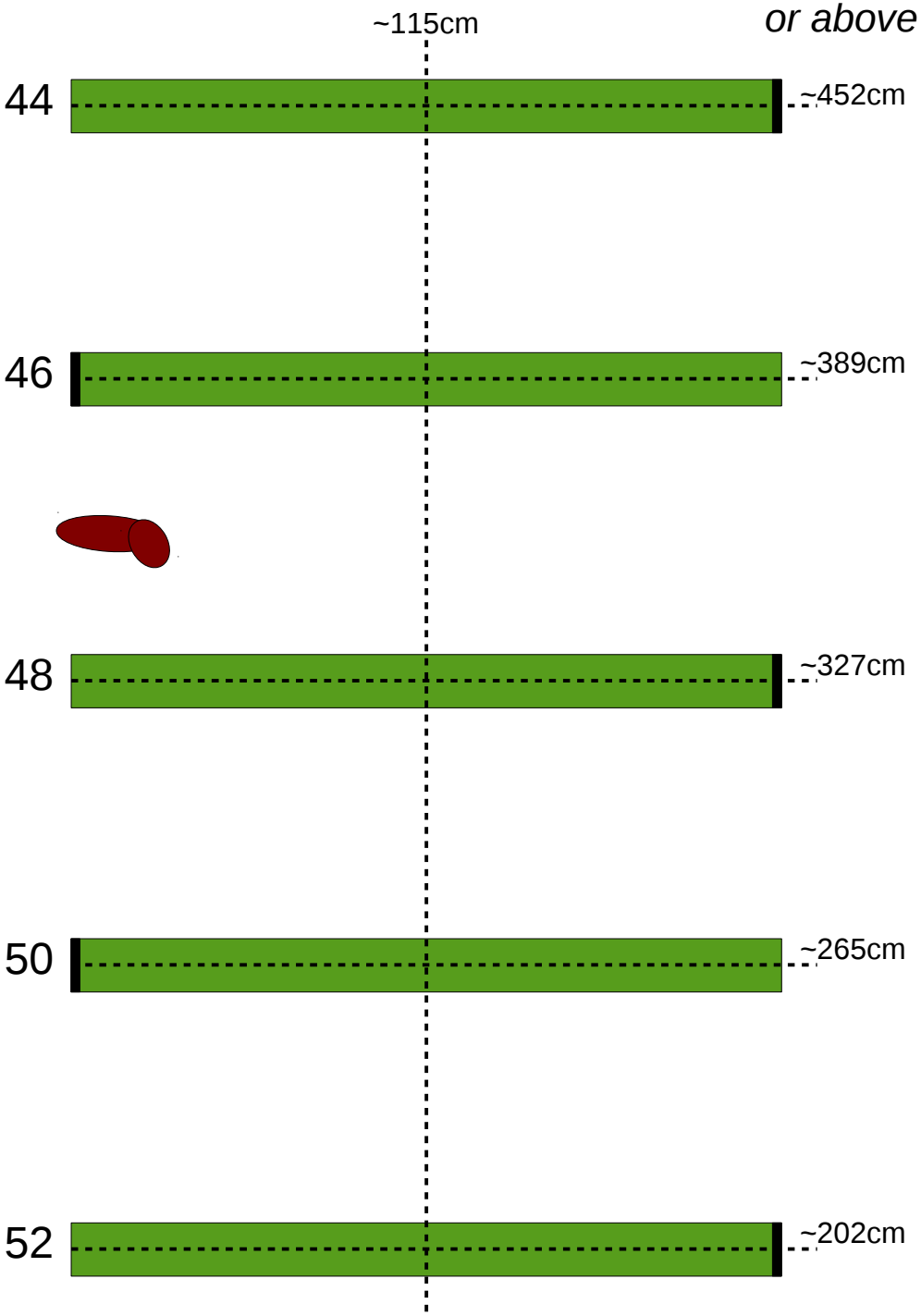
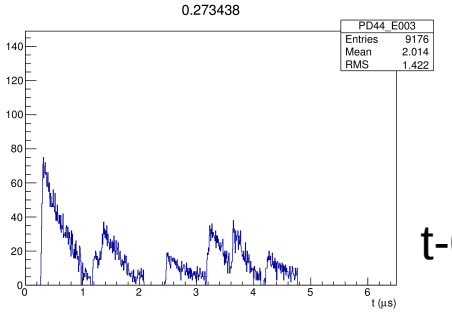
EVENT 3

Approximate t-0 as low edge of first sample at or above 10ADC





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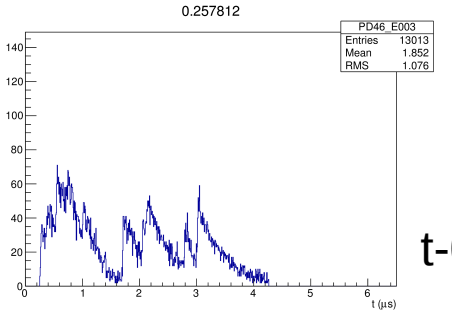

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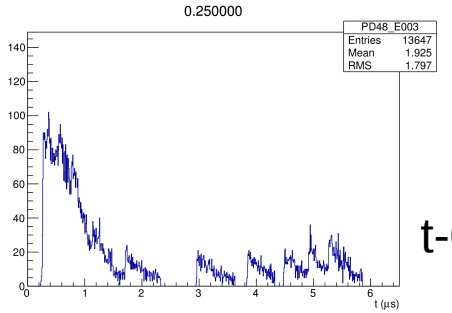

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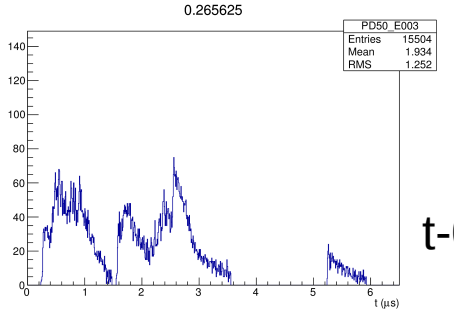

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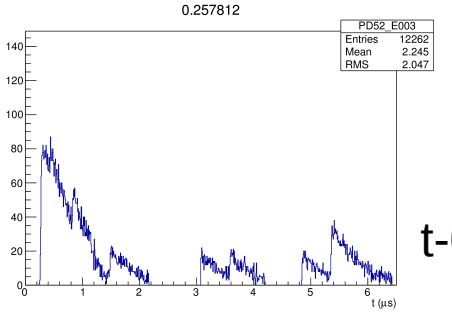

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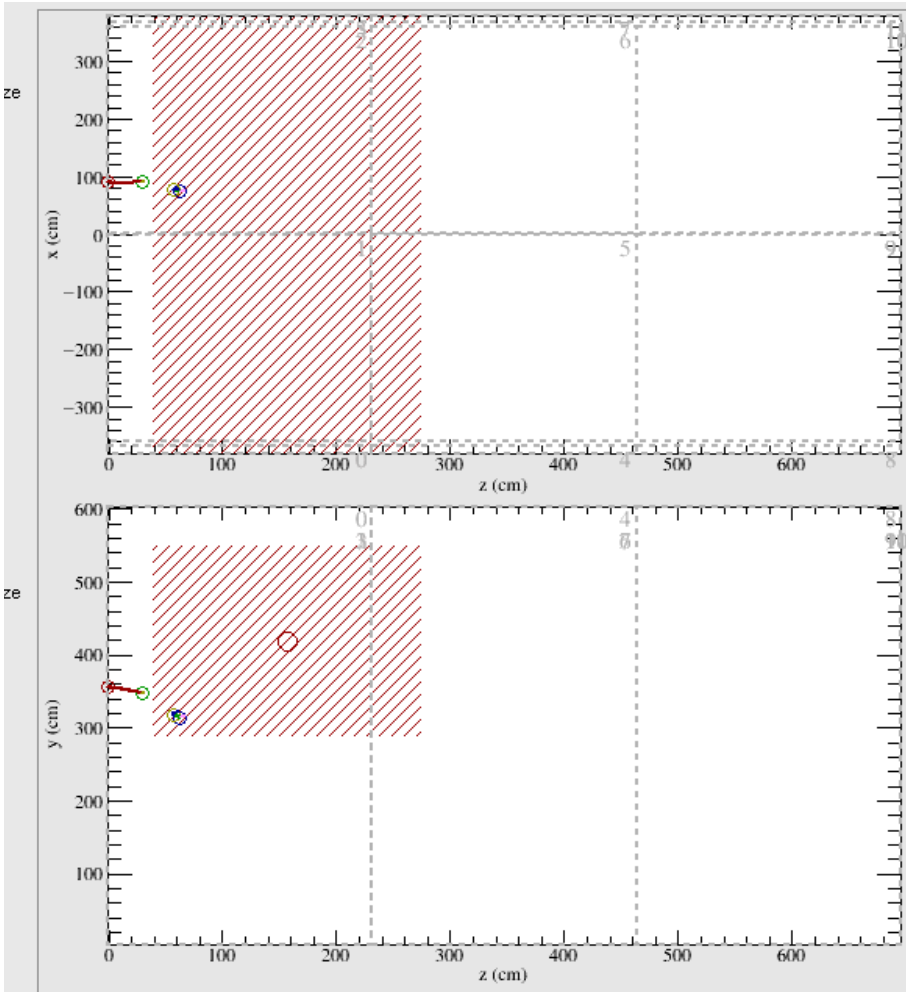
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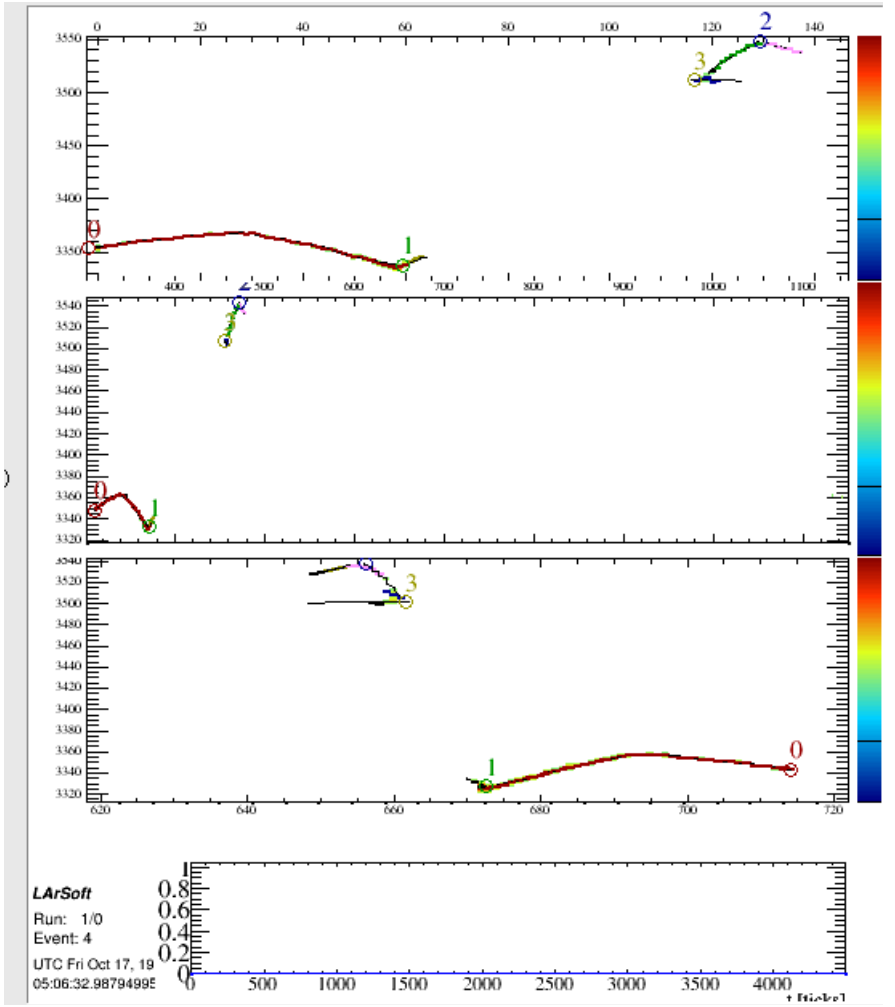
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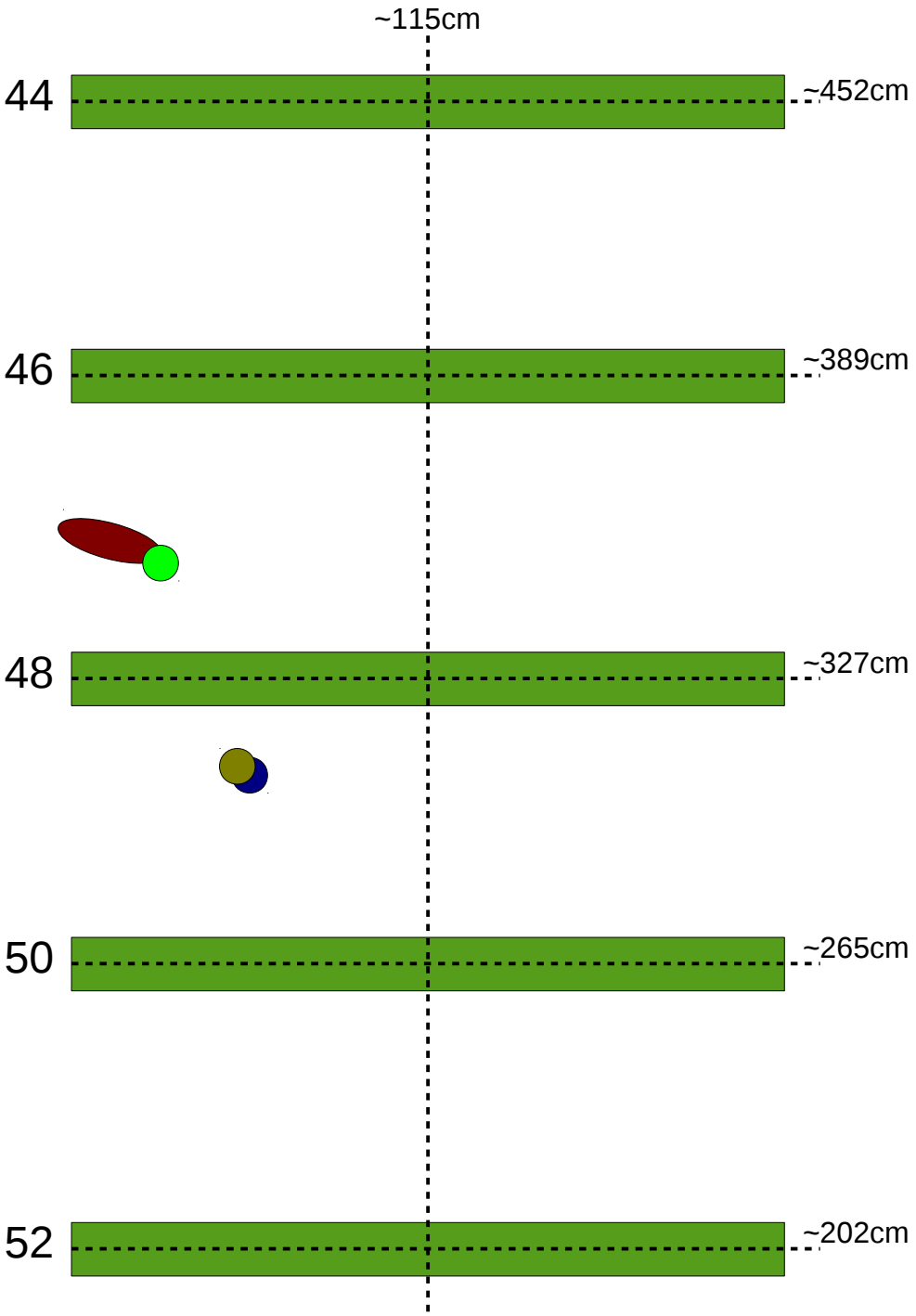

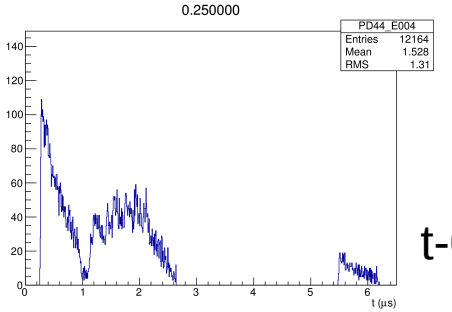

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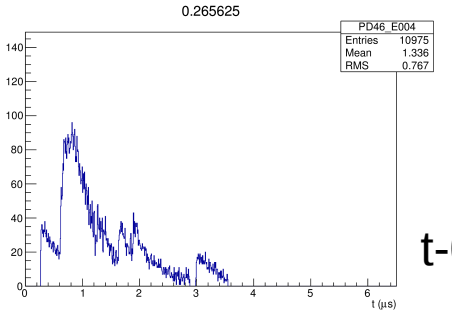

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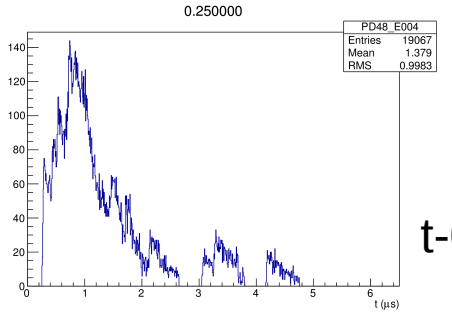

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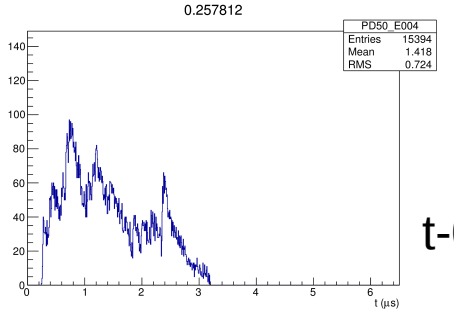

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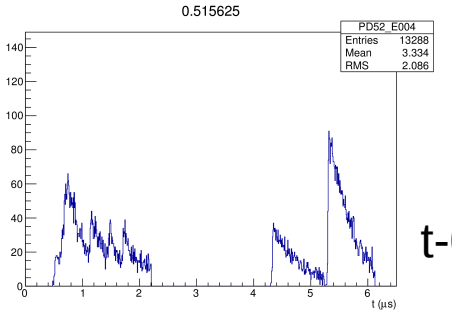

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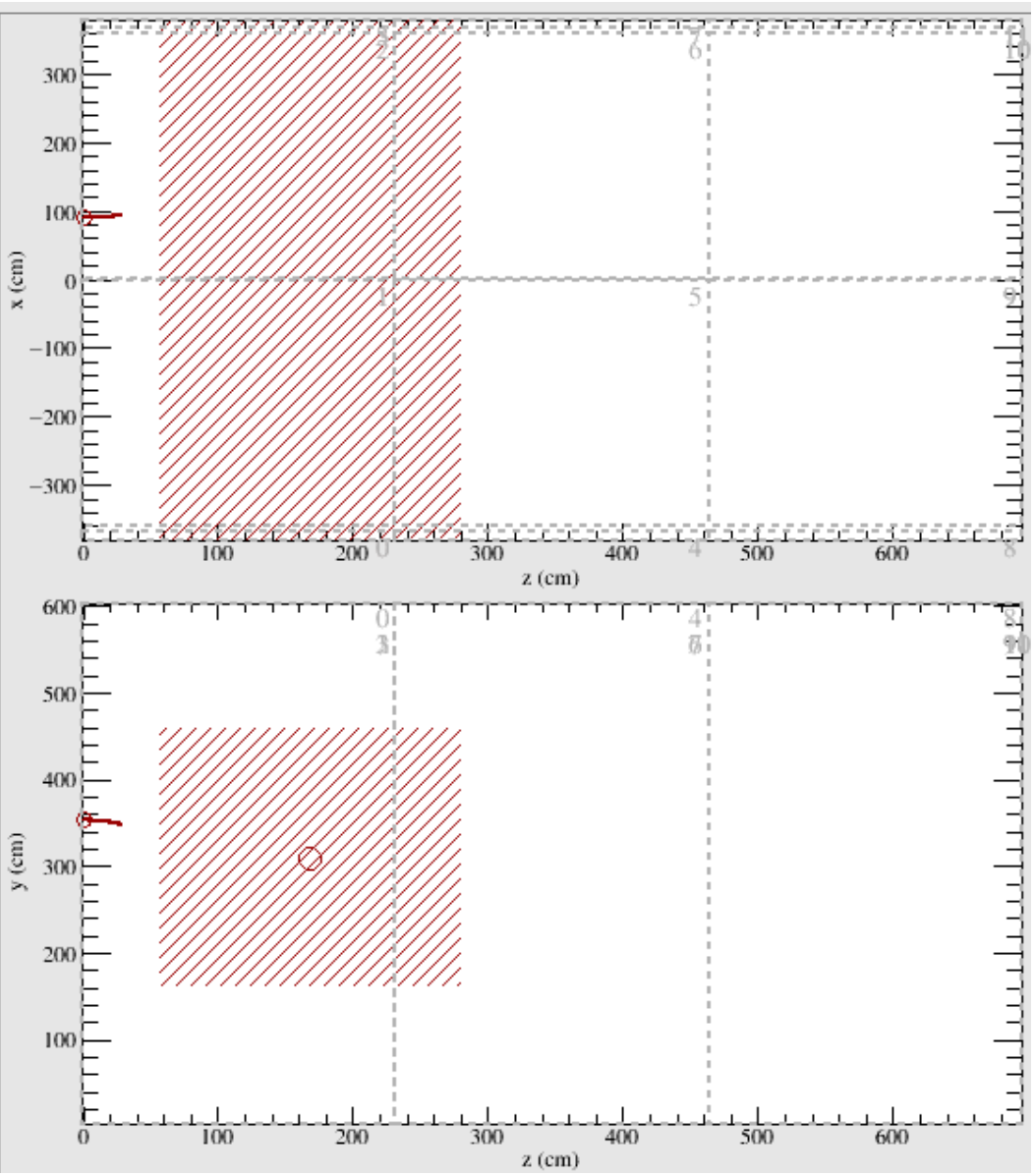
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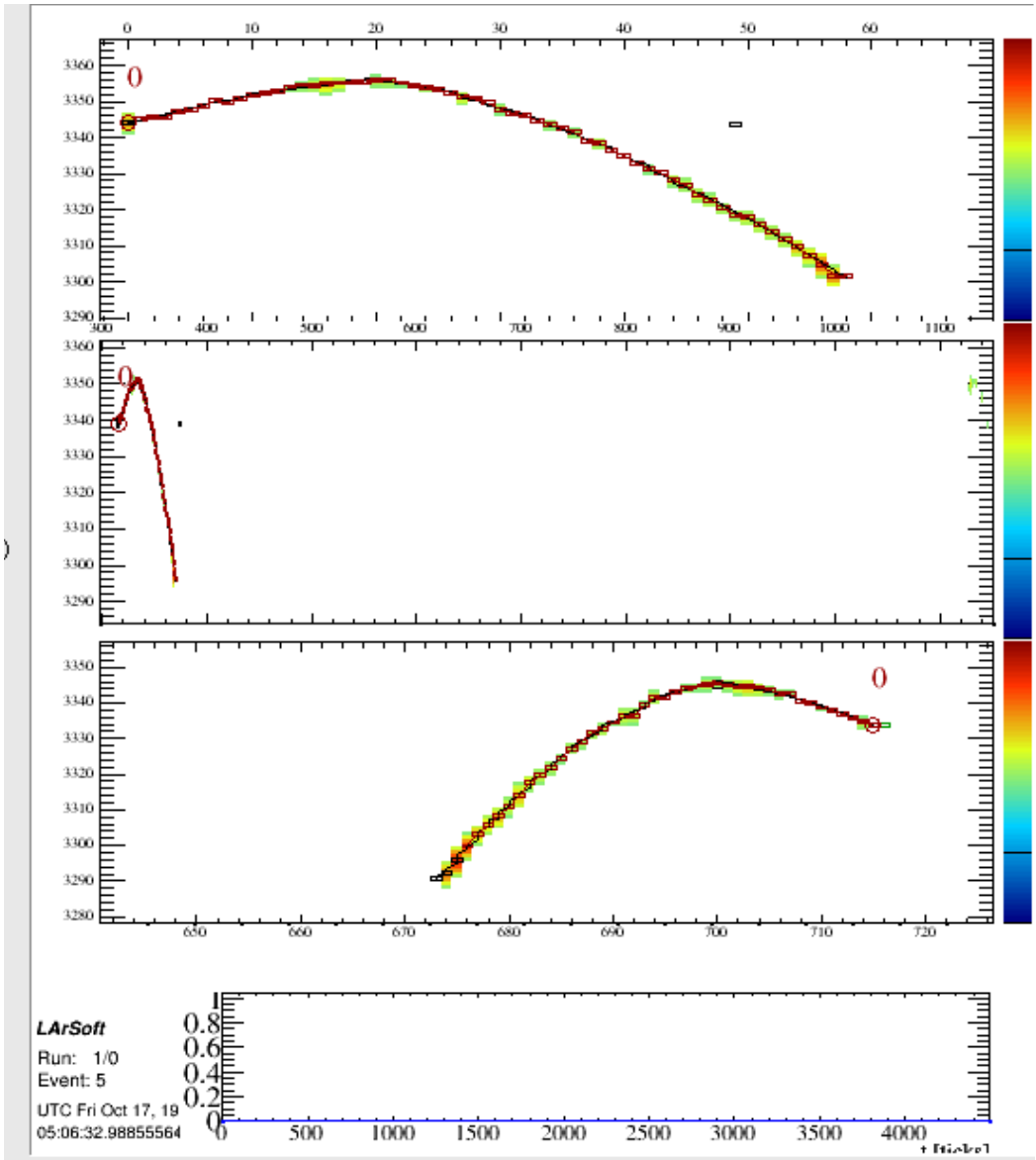
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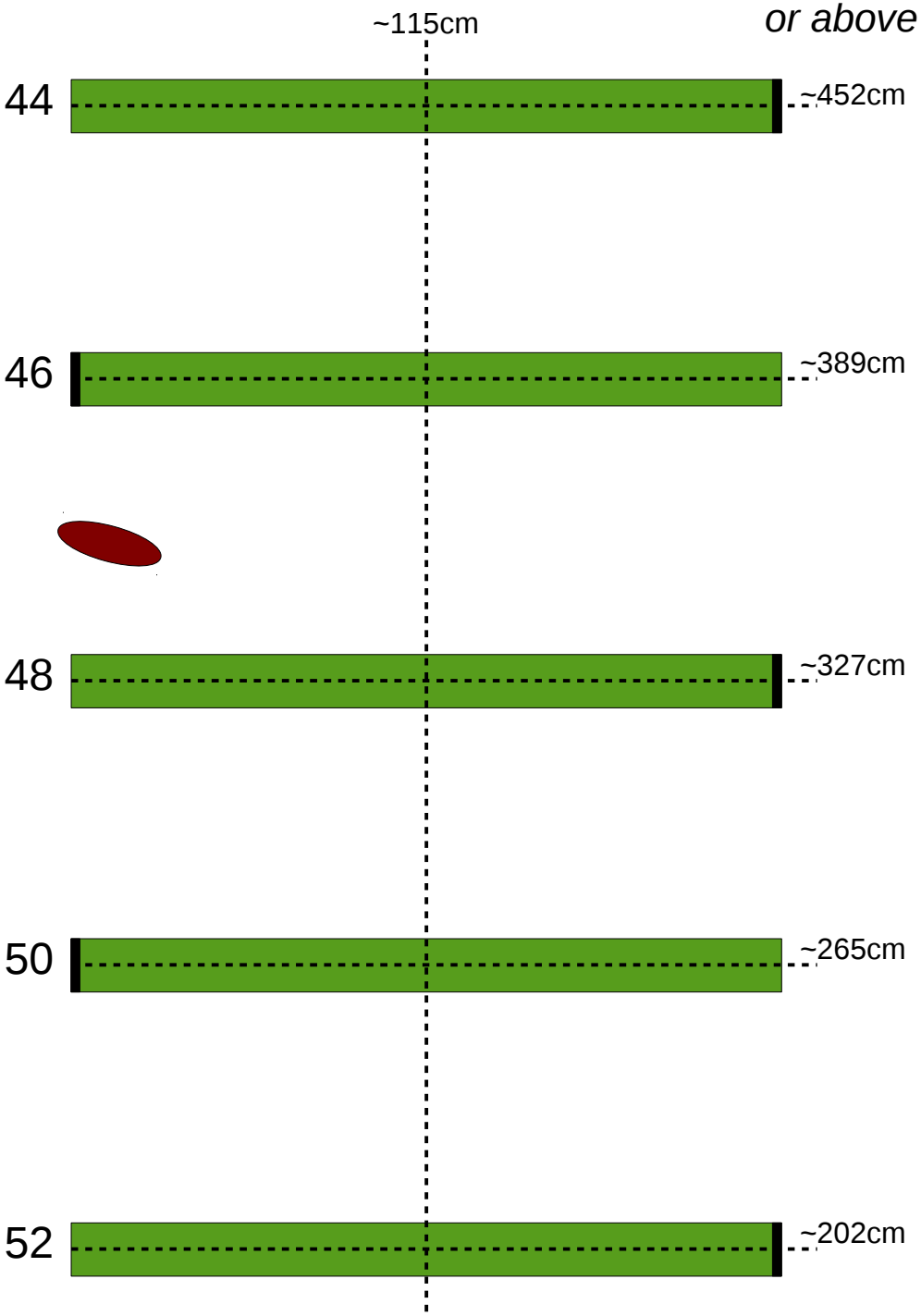
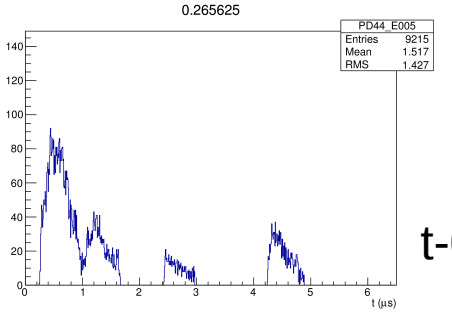
EVENT 5

Approximate t-0 as low edge of first sample at or above 10ADC





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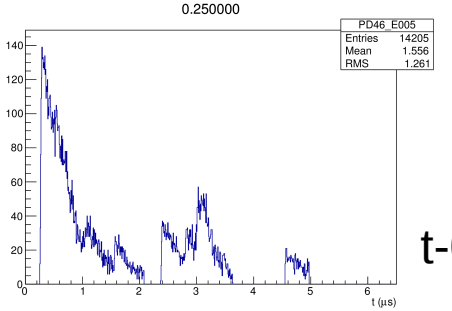

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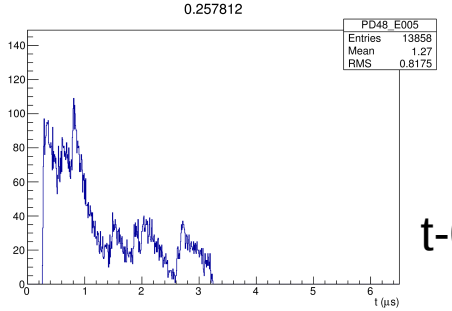

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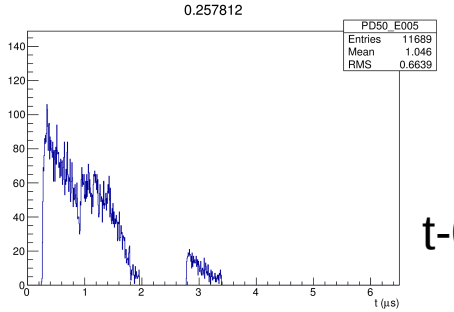
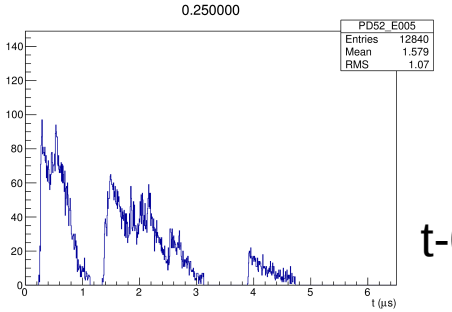
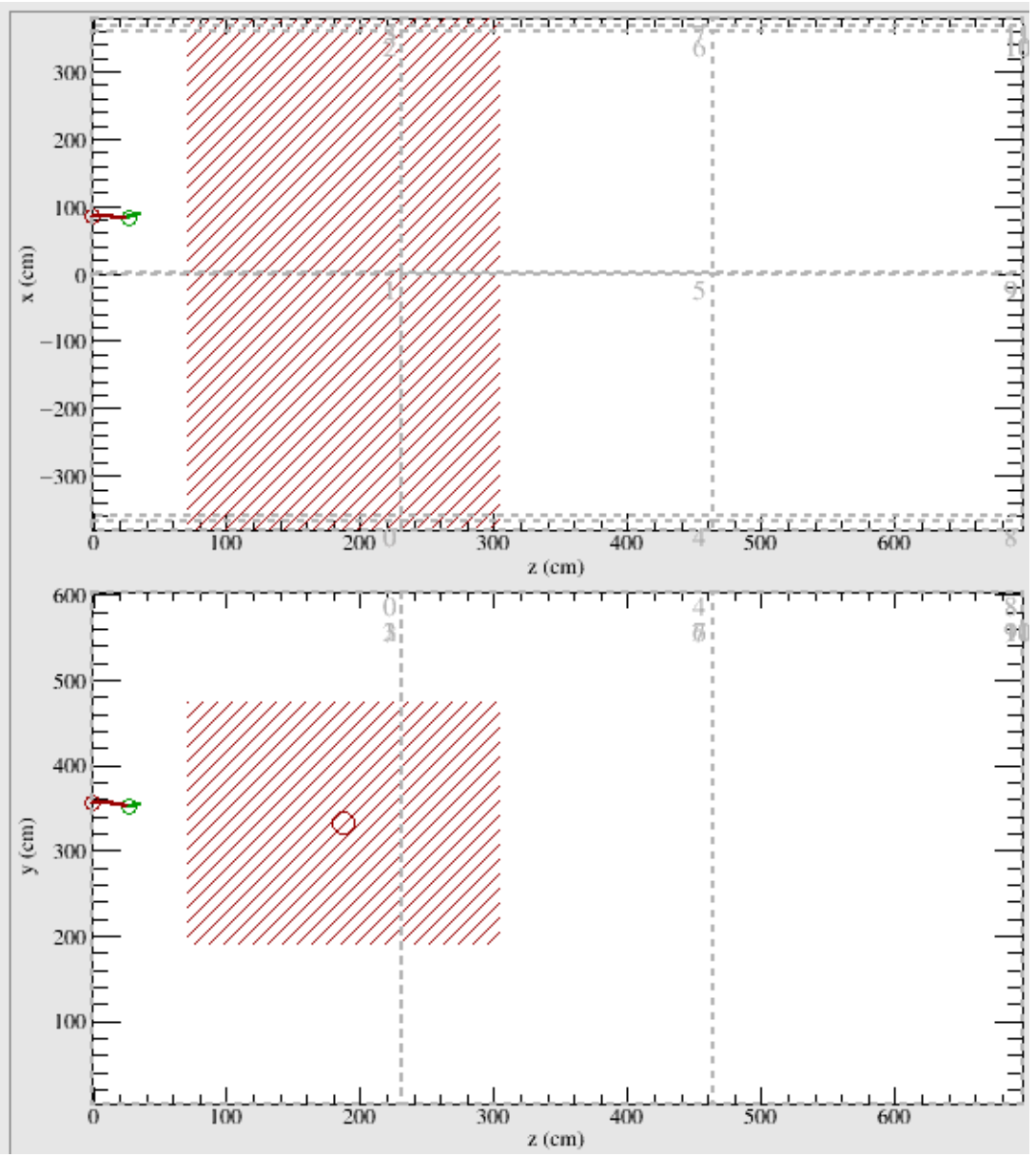


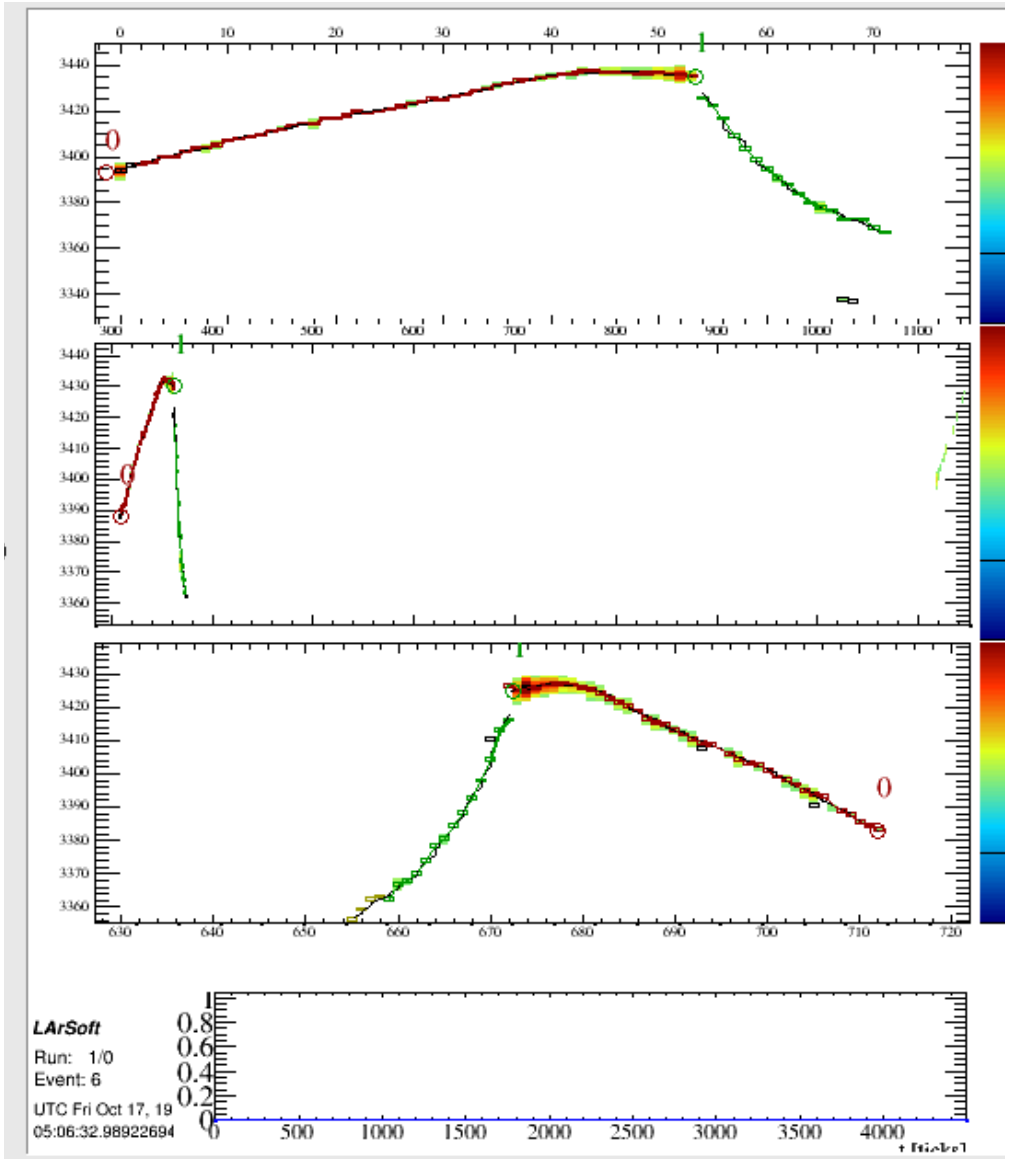
t-0 = .257812 μs



t-0 = .25 μs

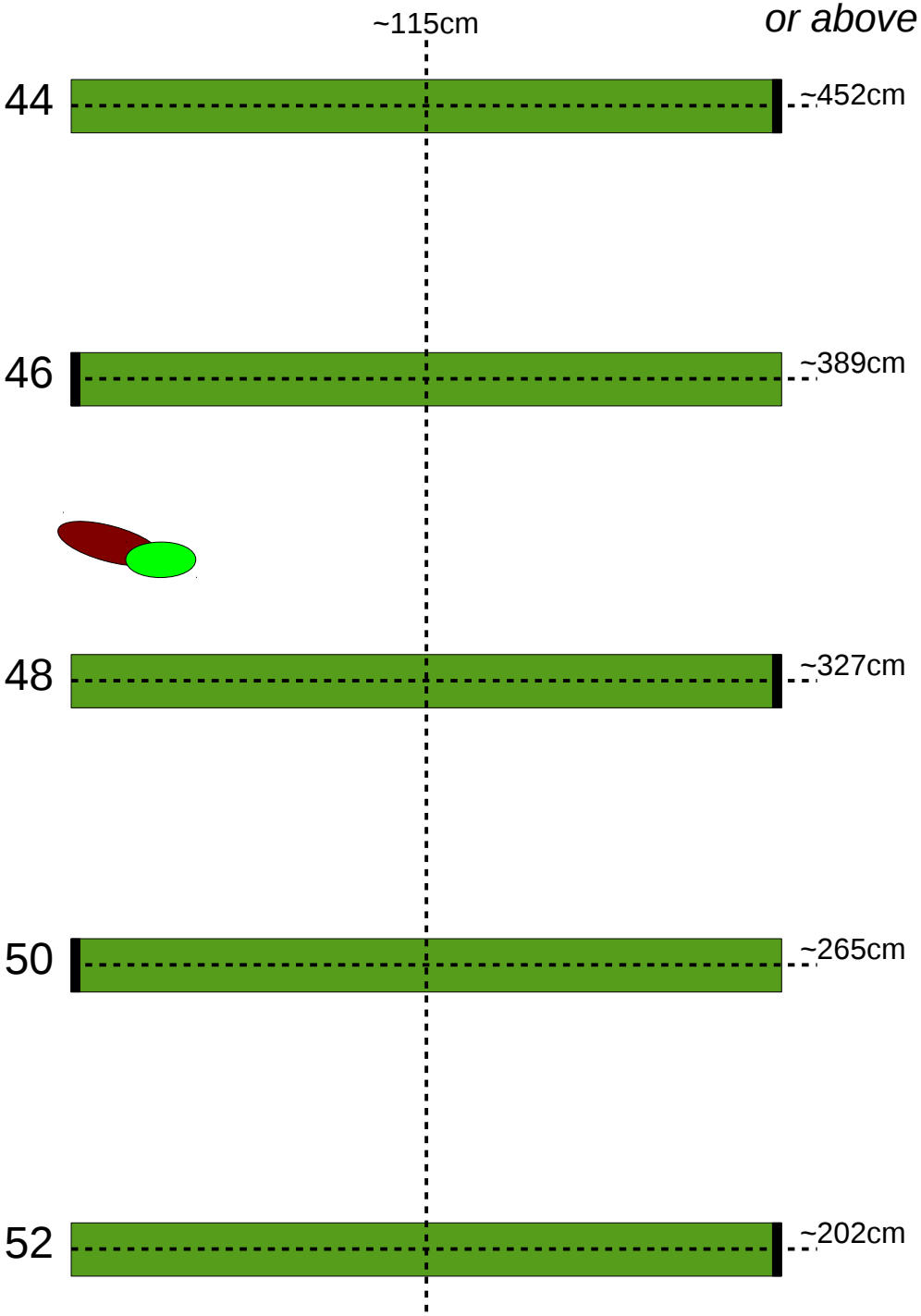
EVENT 6

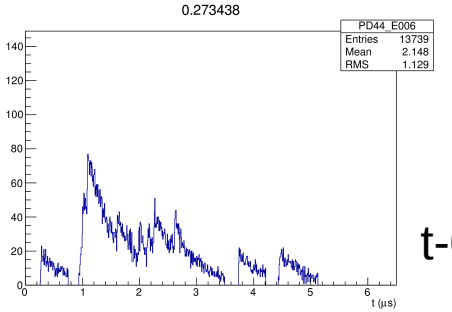

x (cm)
z (cm)
y (cm)
z (cm)


LArSoft
Run: 1/0
Event: 6
UTC Fri Oct 17, 19
05:06:32.98922694

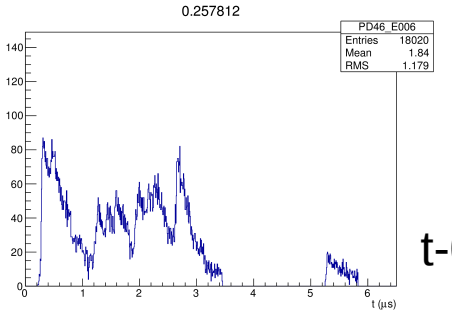
EVENT 6

Approximate t-0 as low edge of first sample at or above 10ADC

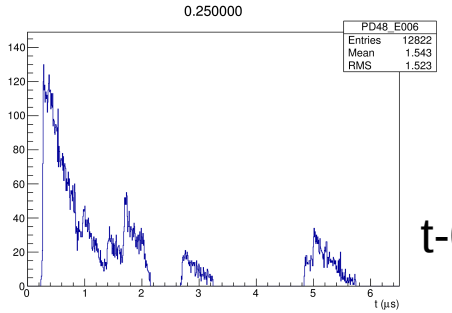




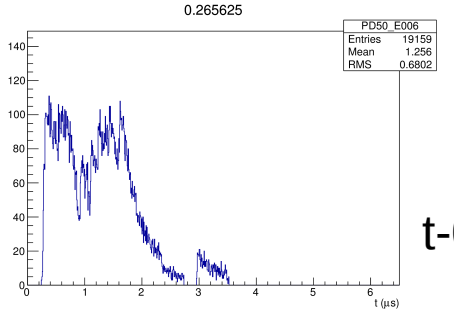
t-0 = .273438 μs



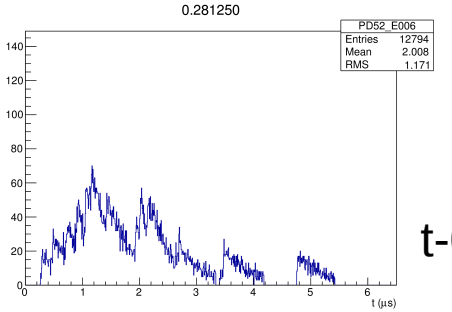
t-0 = .257812 μs



t-0 = .25 μs

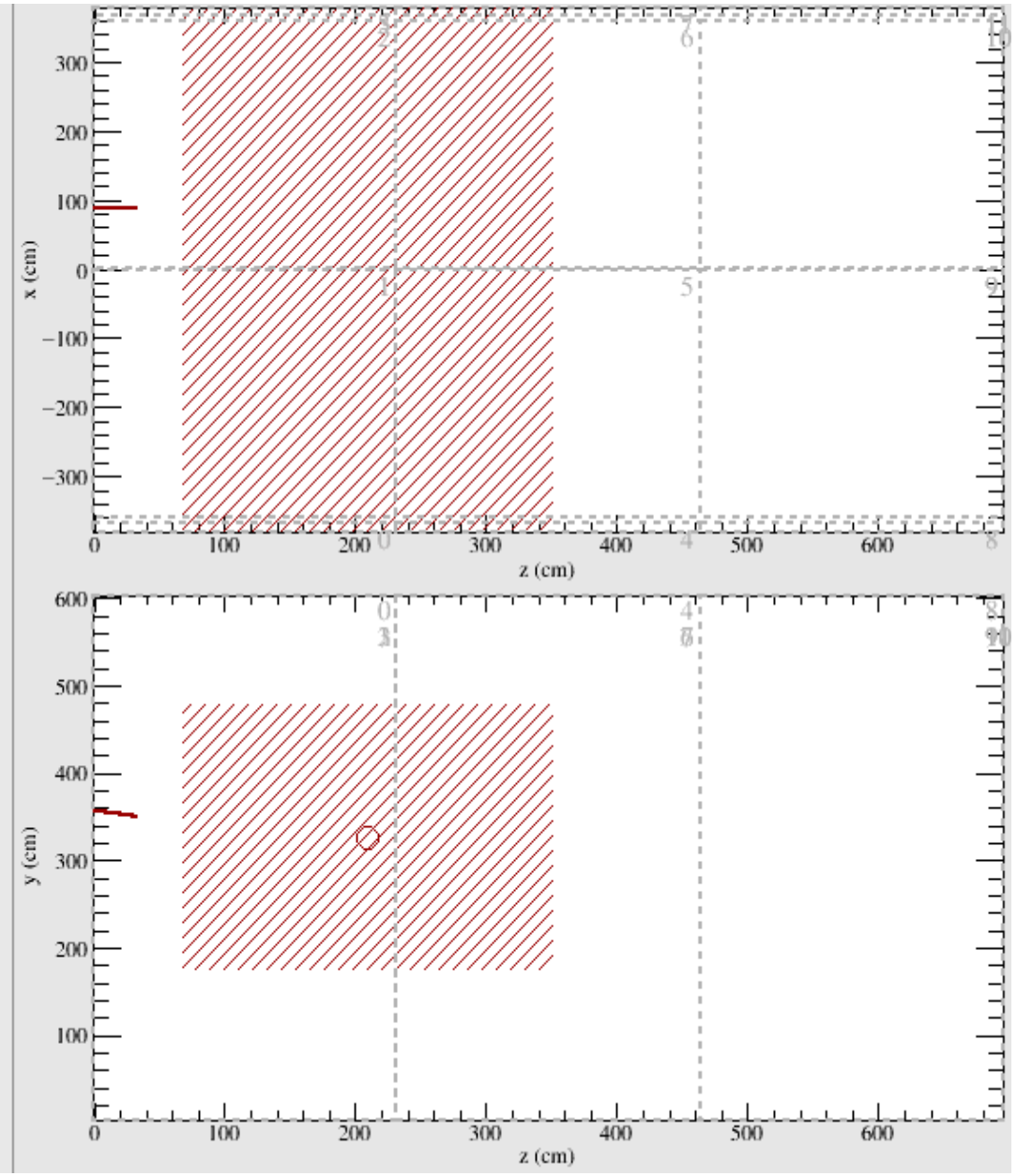


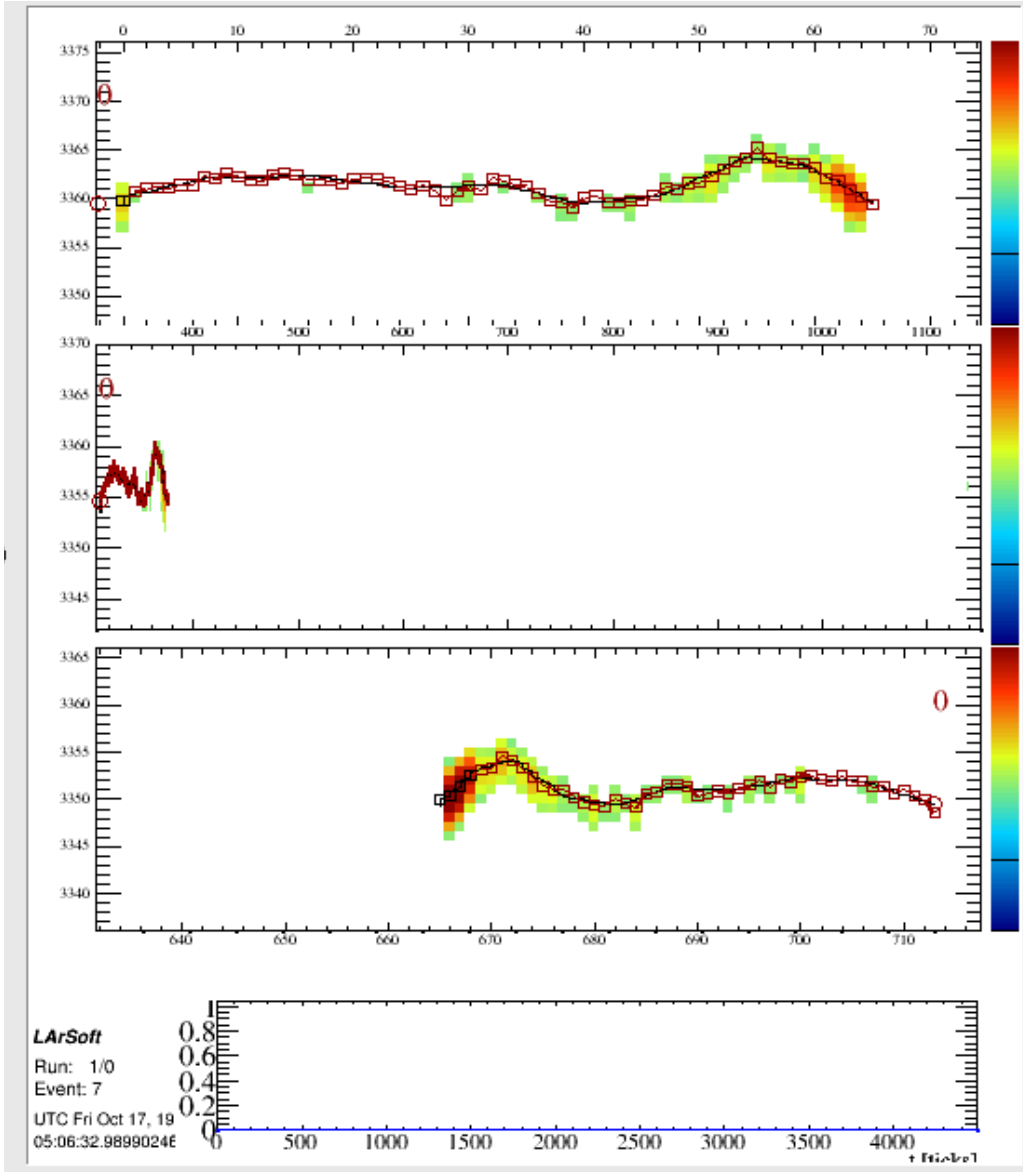
t-0 = .265625 μs



t-0 = .281250 μs

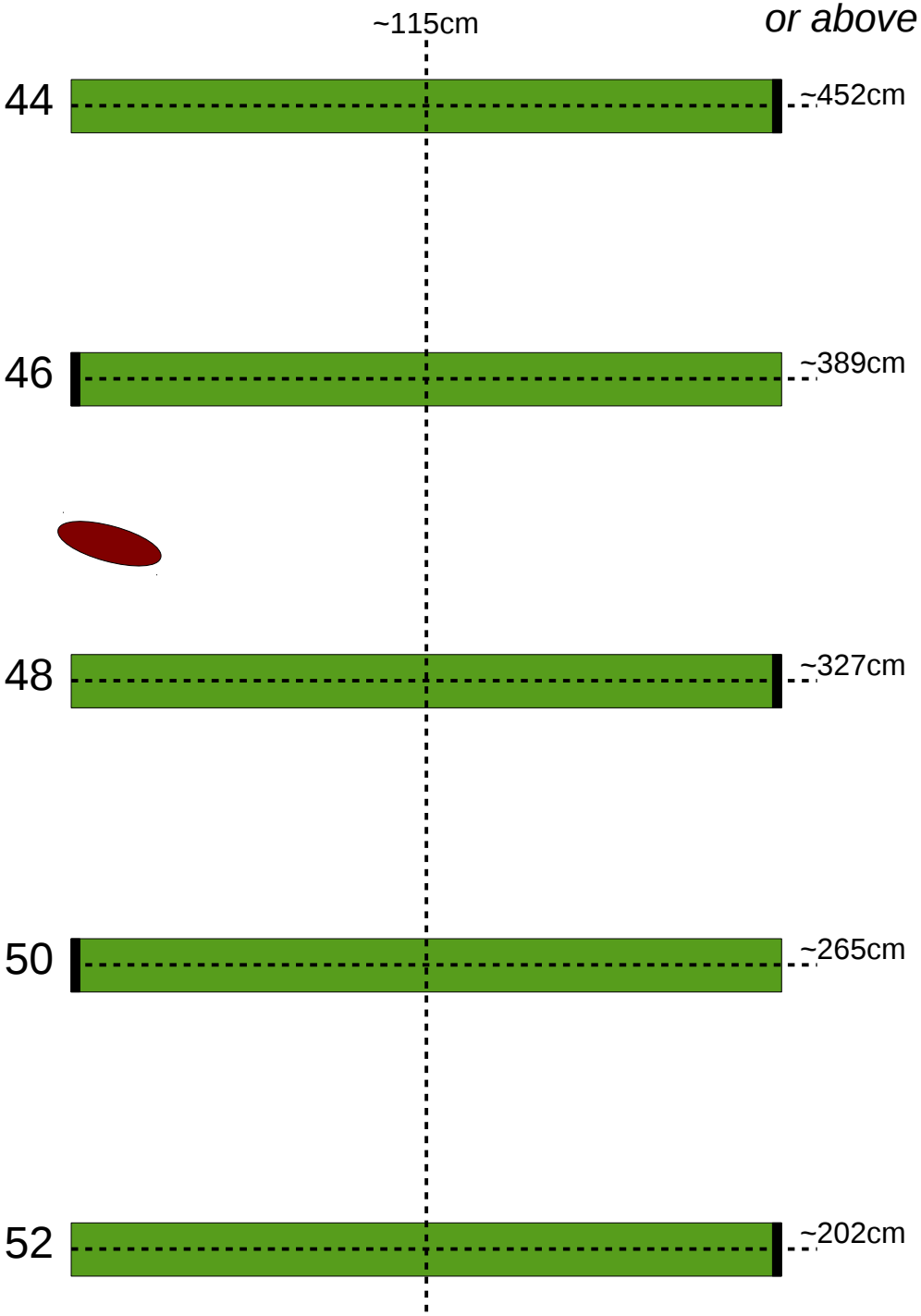
EVENT 7

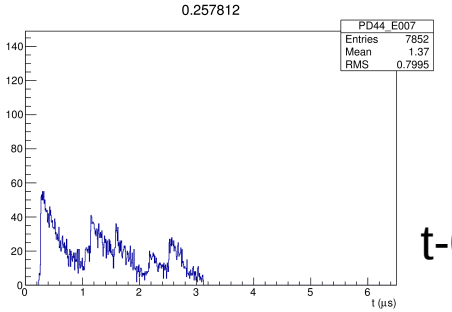

x (cm)
z (cm)
y (cm)
z (cm)


LArSoft
Run: 1/0
Event: 7
UTC Fri Oct 17, 19
05:06:32.9899024E

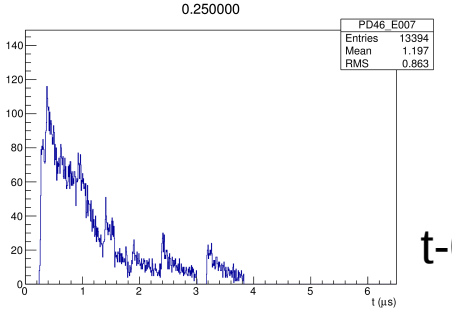
EVENT 7

Approximate t-0 as low edge of first sample at or above 10ADC

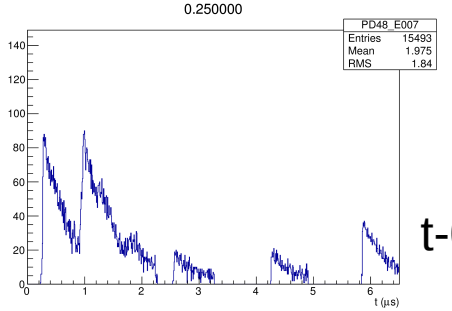




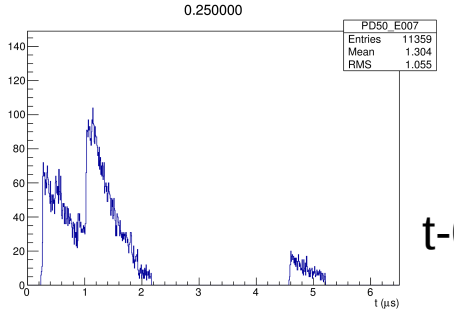
t-0 = .257812 μs



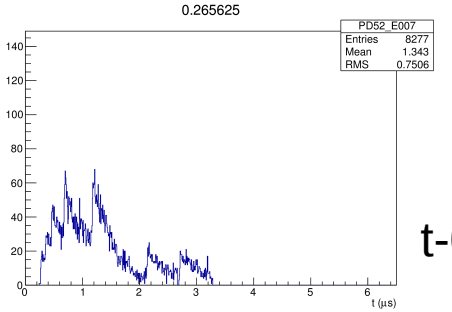
t-0 = .25 μs



t-0 = .25 μs

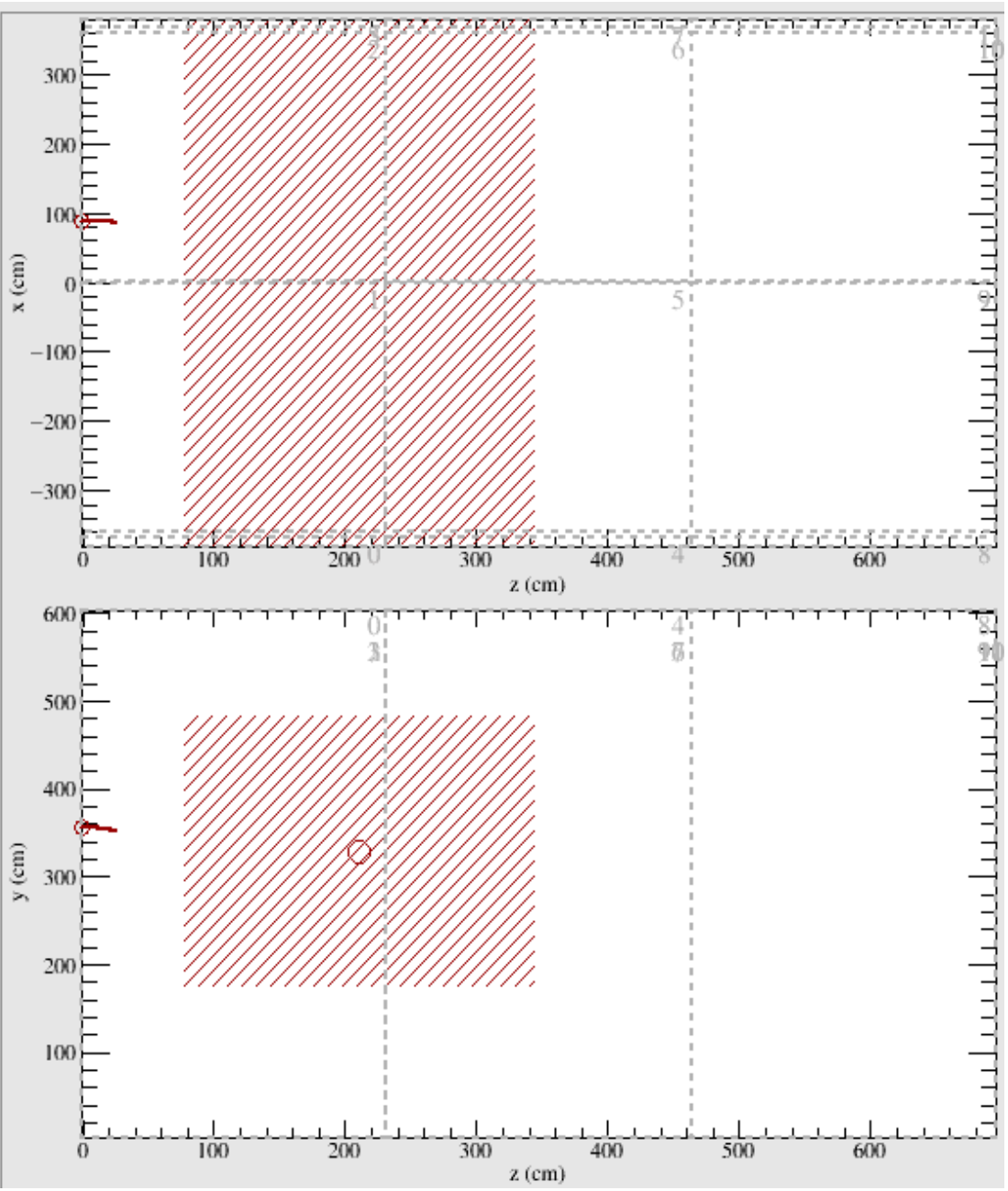


t-0 = .25 μs



t-0 = .265625 μs

EVENT 8


x (cm)
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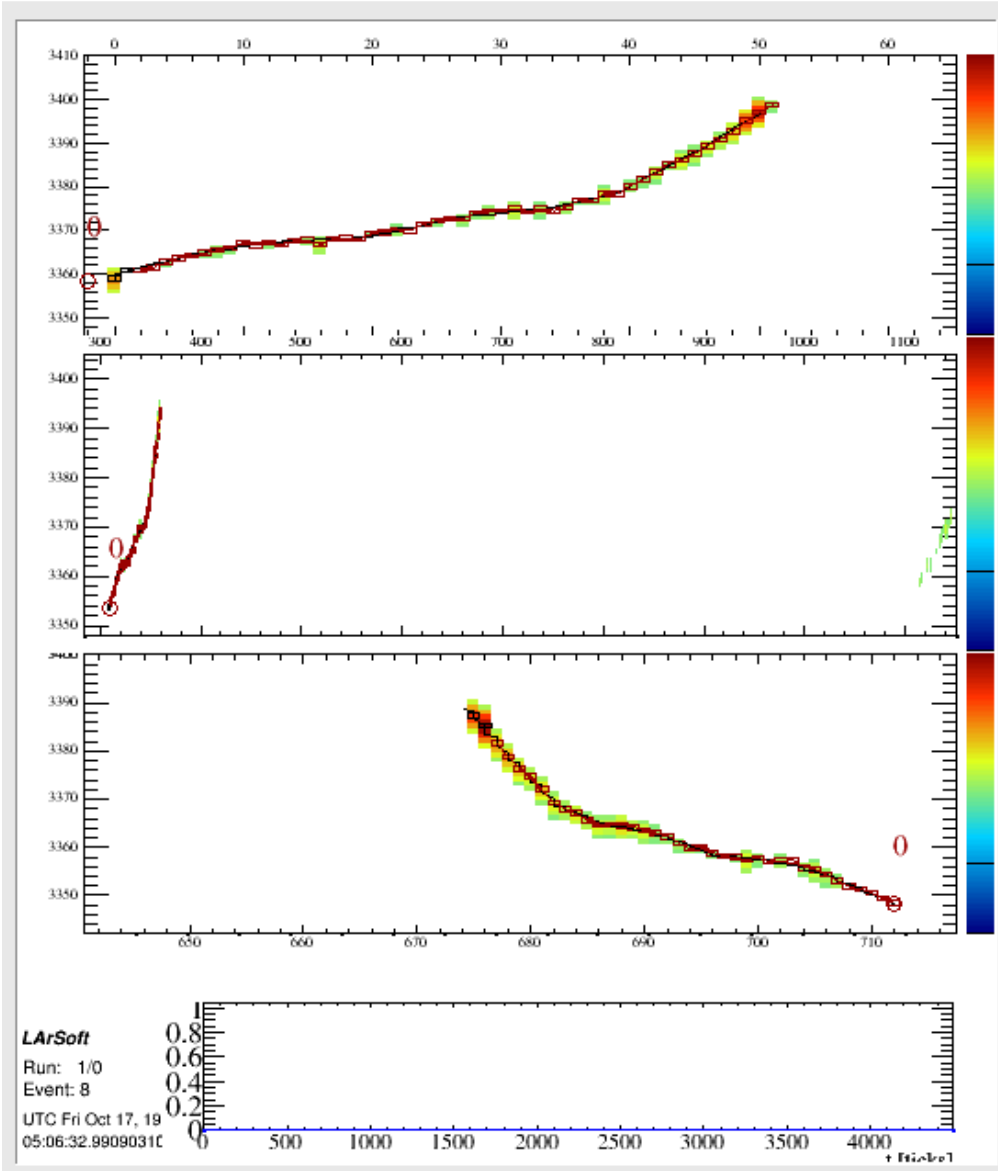
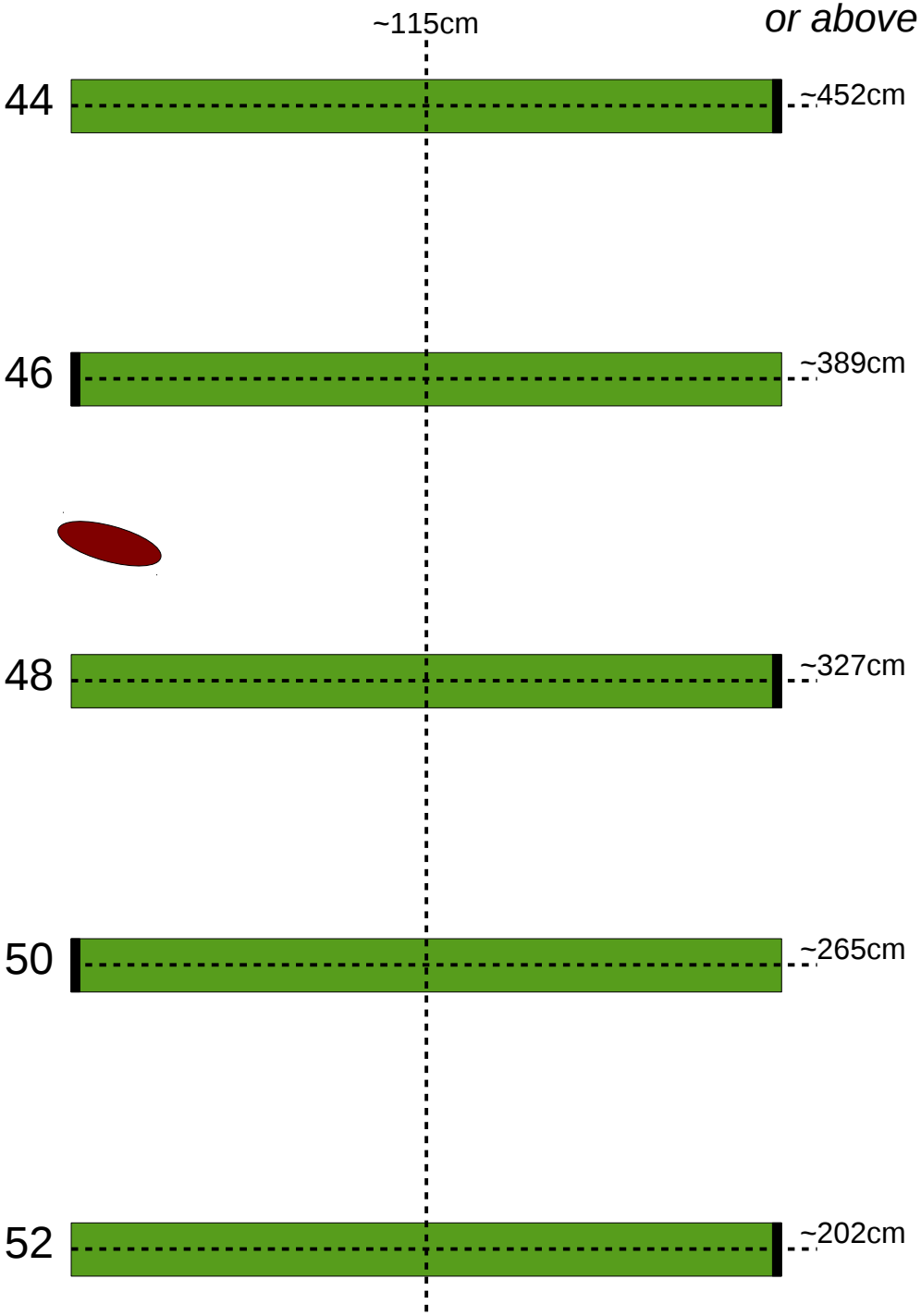
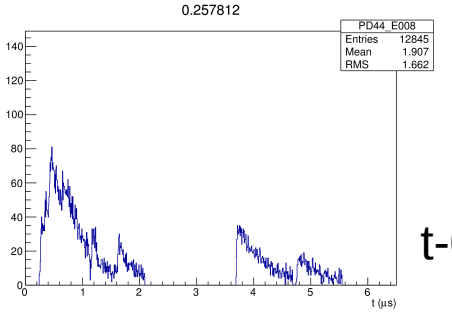
z (cm)


LArSoft
Run: 1/0
Event: 8
UTC Fri Oct 17, 19
05:06:32.9909031(

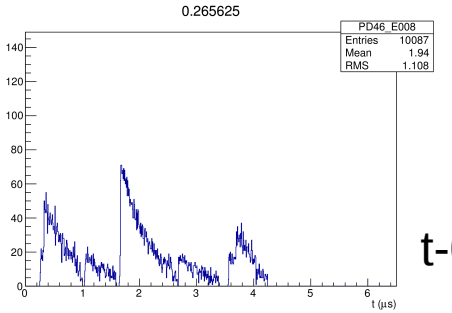
EVENT 8

Approximate t-0 as low edge of first sample at or above 10ADC

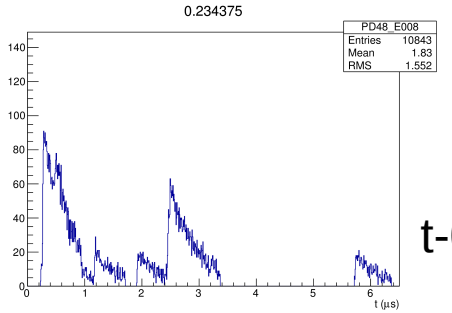




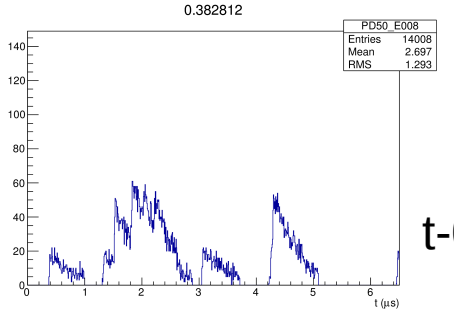
t-0 = .257812 μs



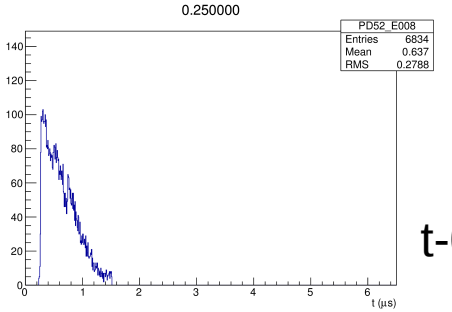
t-0 = .265625 μs



t-0 = .234375 μs

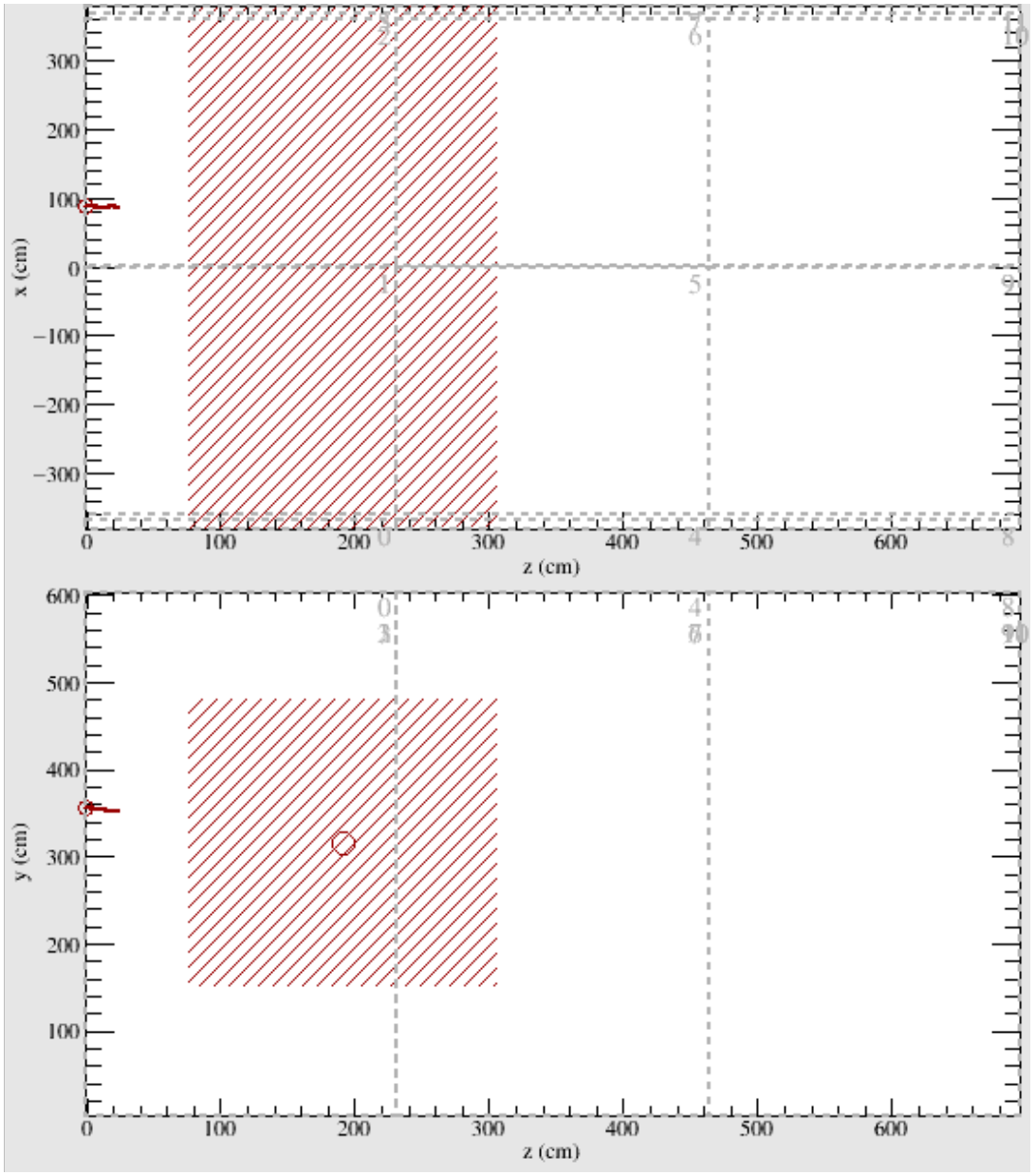


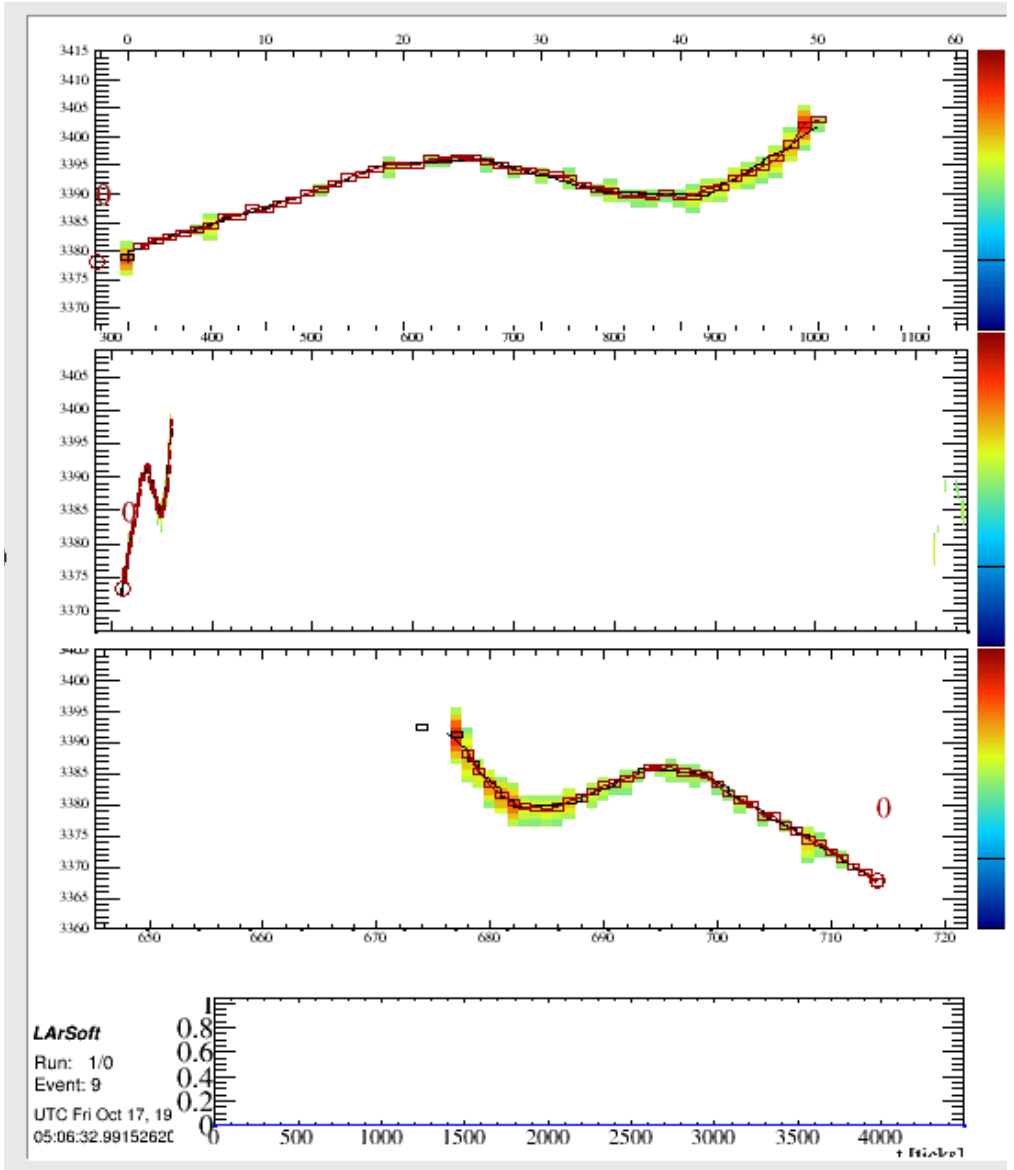
t-0 = .382812 μs



t-0 = .25 μs

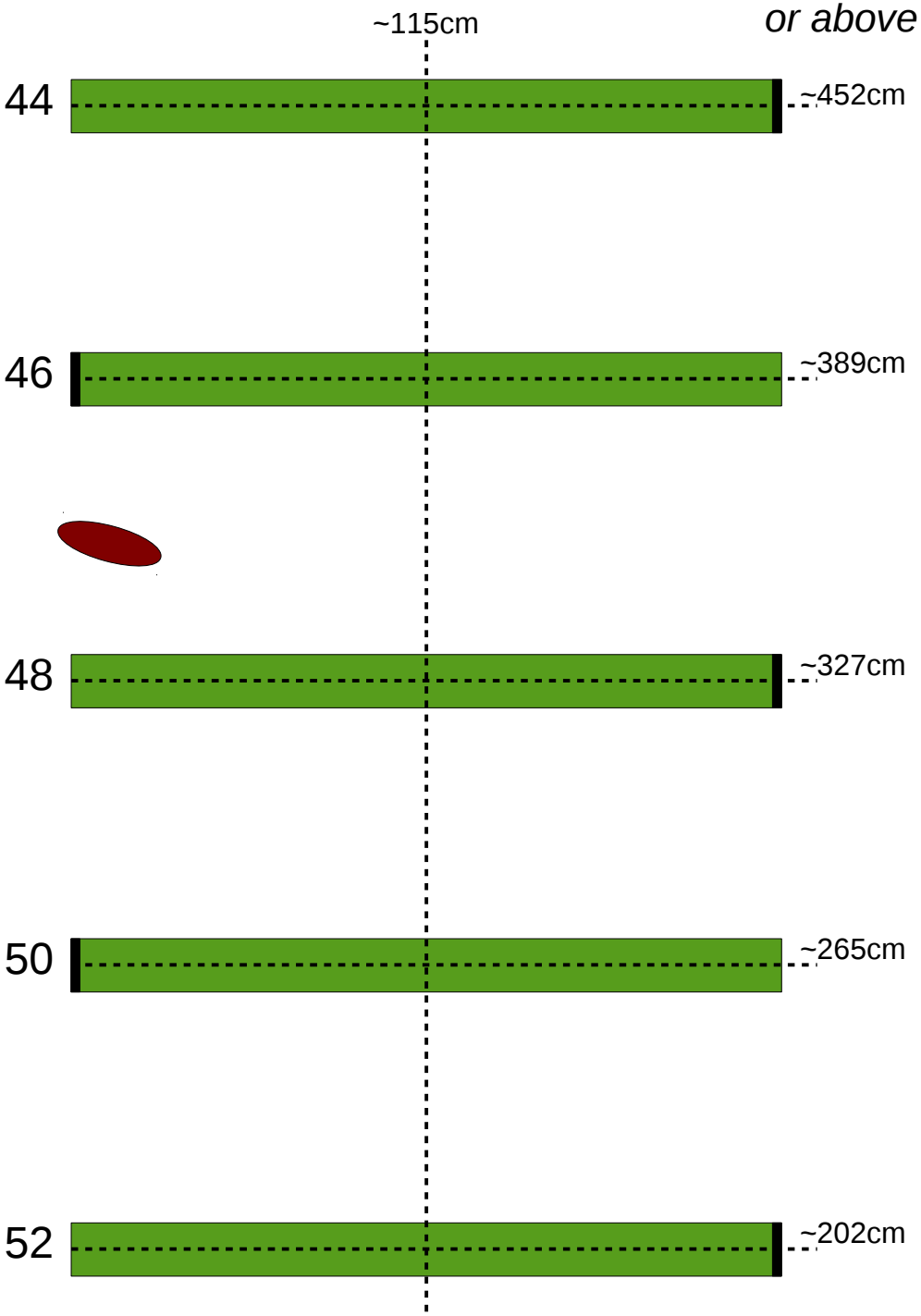
EVENT 9

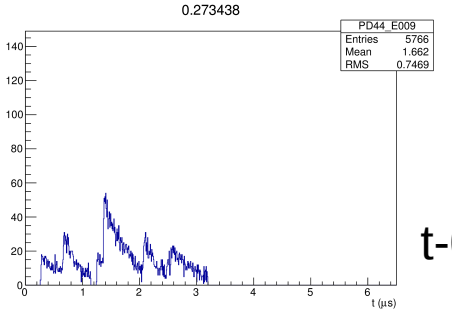

x (cm)
z (cm)
y (cm)
z (cm)


LArSoft
Run: 1/0
Event: 9
UTC Fri Oct 17, 19
05:06:32.9915262(

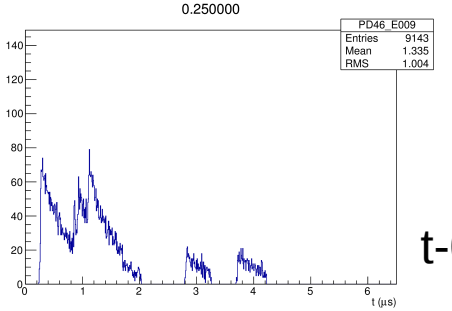
EVENT 9

Approximate t-0 as low edge of first sample at or above 10ADC

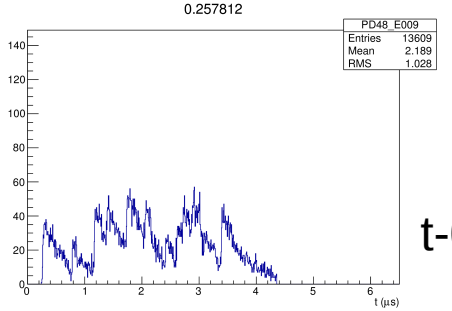




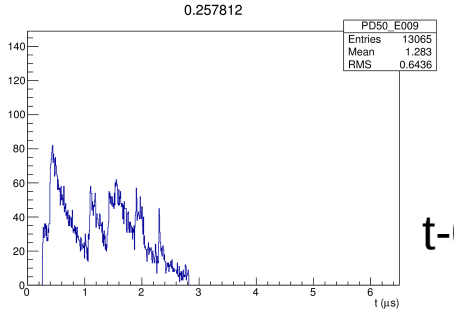
t-0 = .273438 μs



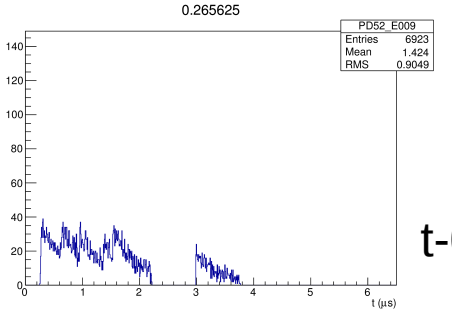
t-0 = .25 μs



t-0 = .257812 μs

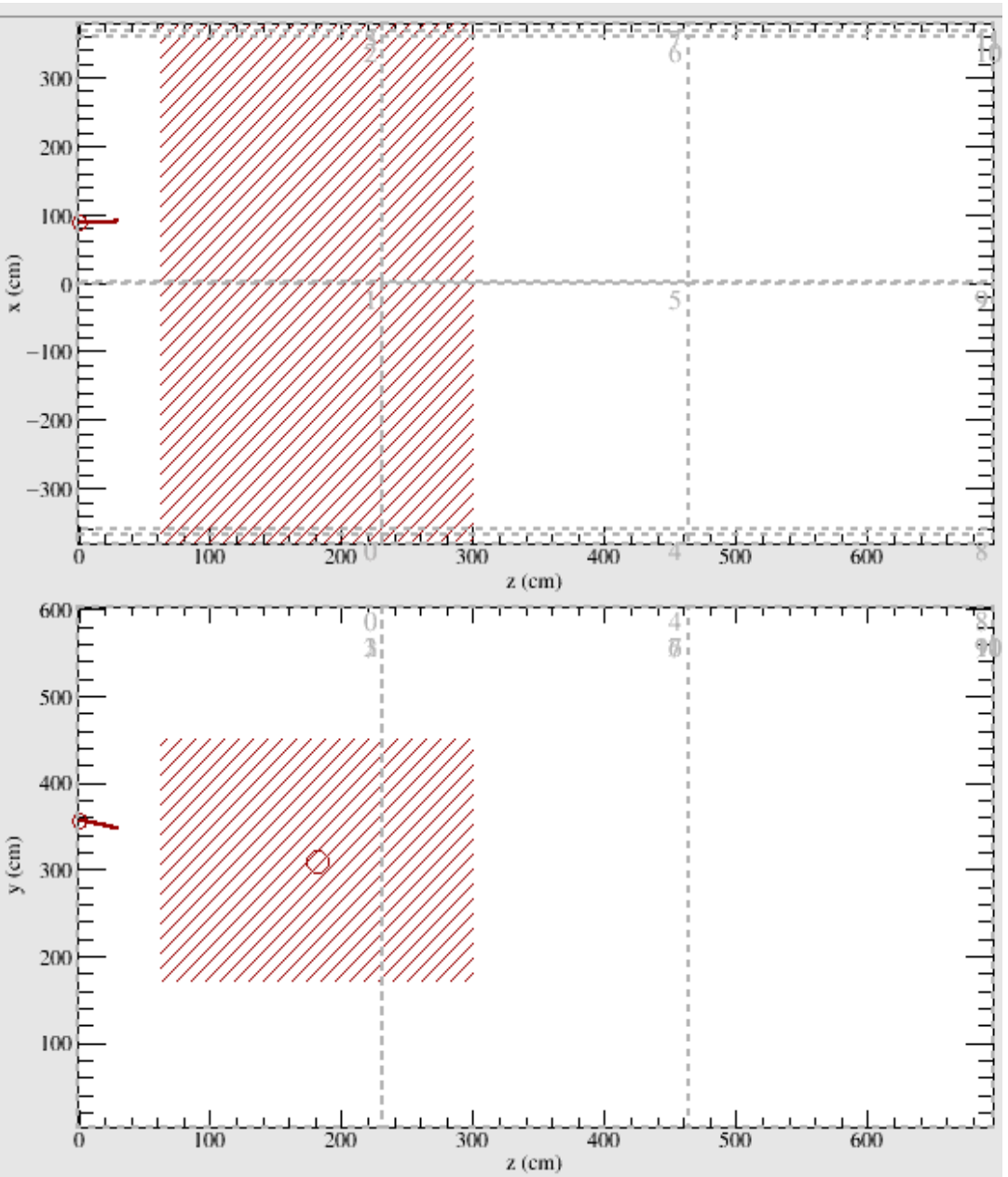


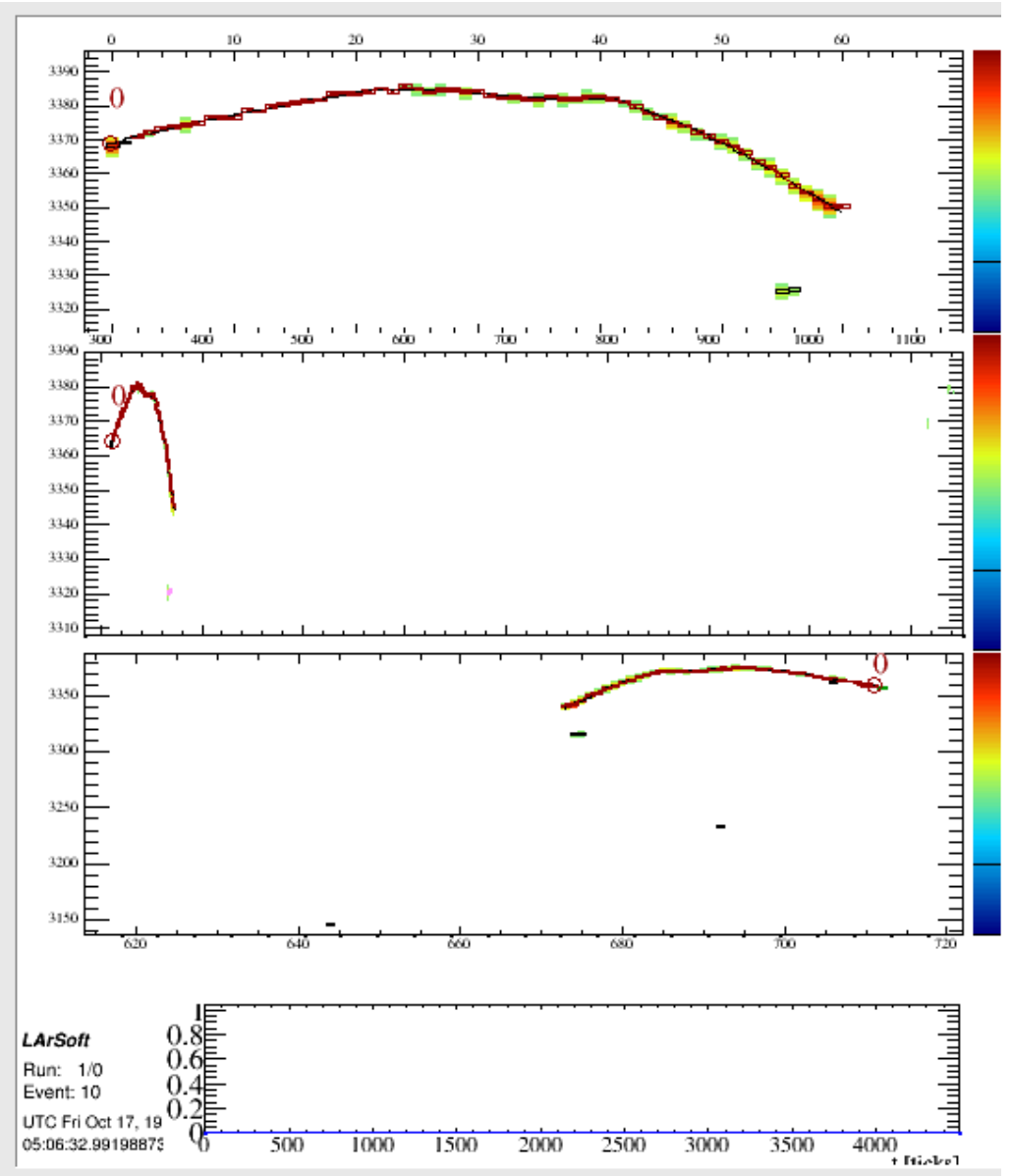
t-0 = .257812 μs



t-0 = .265625 μs

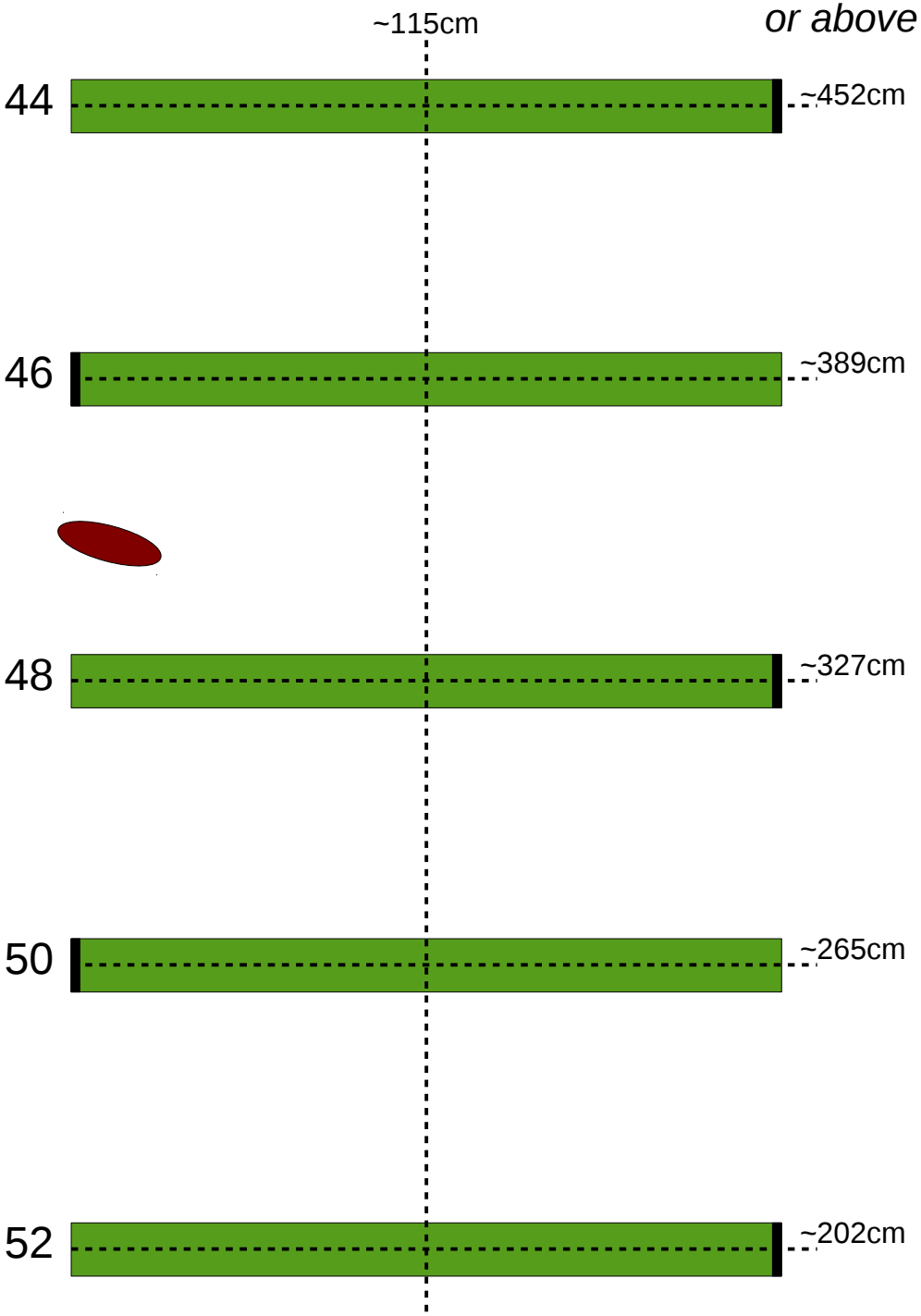
EVENT 10

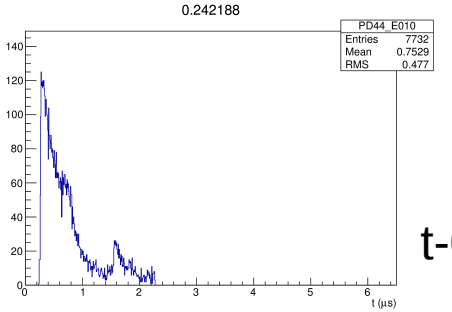

x (cm)
z (cm)
y (cm)
z (cm)


LArSoft
Run: 1/0
Event: 10
UTC Fri Oct 17, 19
05:06:32.99198873

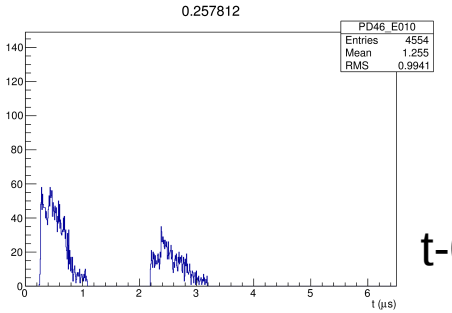
EVENT 10

Approximate t-0 as low edge of first sample at or above 10ADC

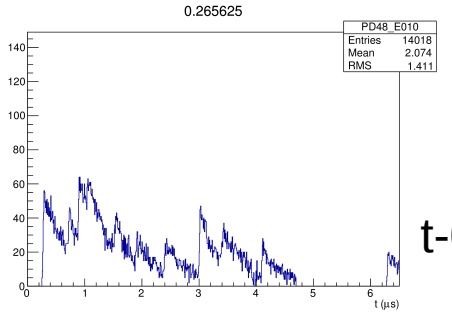




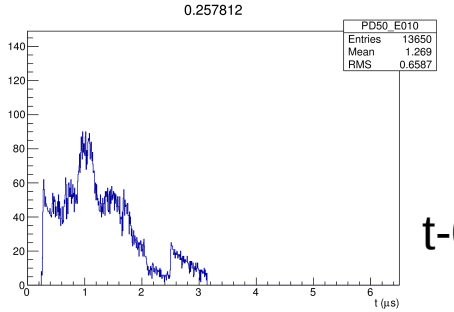
t-0 = .242188 μs



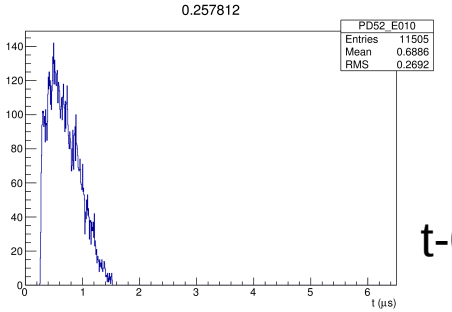
t-0 = .257812 μs



t-0 = .265625 μs



t-0 = .257812 μs



t-0 = .257812 μs